Energy Research and Development Division
STAFF REPORT

NATURAL GAS RESEARCH AND DEVELOPMENT

2013 Annual Report

CALIFORNIA
ENERGY COMMISSION

Edmund G. Brown Jr., Governor

OCTOBER 2013

CEC-500-2013-111

CALIFORNIA ENERGY COMMISSION

Linda Schrupp
Primary Authors

Prepared for:

California Energy Commission

Nicole Smith
Jesselyn Rosales
Project Managers

Fernando Pina
Office Manager
ENERGY SYSTEMS RESEARCH OFFICE

Laurie ten Hope
Deputy Director
RESEARCH AND DEVELOPMENT DIVISION

Robert P. Oglesby
Executive Director

ACKNOWLEDGEMENTS

The authors appreciate the contributions from the following Energy Research and Development Division staff:

Aldas, Rizaldo
Benson, Andrew
Doll, Jeffrey
Franks, Janna
Gautam, Anish
Harville, Jason
Kandel, Adrienne
Karkheck, Johann
Kravitz, Raquel
Lozano, Michael
Meister, Brad
Magaña, Pilar
Sotero, Maria

PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The Energy Research and Development Division conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The Energy Research and Development Division strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

Energy Research and Development Division funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Natural Gas Research and Development is the staff report for the 2013 Natural Gas Annual Report project conducted by Energy Research and Development. The information from this project contributes to Energy Research and Development Division's Natural Gas Program.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

The California Energy Commission's research and development (R&D) work was initiated in 1996 when the California Legislature enacted Assembly Bill 1890 (Brulte, Chapter 854, Statutes of 1996), California's electric utility restructuring legislation. This law required that funds be collected annually from California's three investor-owned electric utilities and deposited in the Public Interest Energy Research and Development Account, to be invested by the Energy Commission in public interest energy-related research, development, and demonstration.

Similar legislation was enacted in 2000 with Assembly Bill 1002 (Wright, Chapter 932, Statues of 2000), which required the California Public Utilities Commission (CPUC) to impose a surcharge on all natural gas consumed in California to fund various energy efficiency programs, as well as public interest research and development to benefit natural gas ratepayers. Assembly Bill 1002 also required the CPUC to designate an entity to administer the research component of AB 1002. In 2004, the California Public Utilities Commission issued Decision 04-08-010, which designated the Energy Commission as the administrator for the research funds.

The *Natural Gas Research and Development 2013 Annual Report* highlights project successes and benefits, and covers completed projects and current research from July 1, 2012, through June 30, 2013. In fiscal year 2012-2013, the California Energy Commission administered $24 million to natural gas research, development, and demonstration projects geared toward improving the safety and security of natural gas in California.

Keywords: California Energy Commission, California Public Utility Commission, combined heat and power, distributed generation, hydraulic fracturing, natural gas pipelines, renewable energy

Please use the following citation for this report:

Schrupp, L. 2013. Energy Research and Development Division. 2013. ***Natural Gas Research and Development 2013 Annual Report.*** California Energy Commission. Publication Number: CEC-500-2013-XXX

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Natural gas satisfies approximately one-third of the state's total primary energy demand.[1] Almost half of California's natural gas consumption is used to generate electricity, while the remainder is used in industrial processes or by the residential and commercial sectors for space and water heating and cooking. Emerging transportation technologies — such as natural gas-fueled vehicles — are adding to California's natural gas consumption.

Natural gas-related energy research benefits California's economy, environment, and ratepayers by developing technologies, tools, methods, and insights that increase energy efficiency and reduce pollution and greenhouse gas emissions. Consistent with its statutory purpose, the California Energy Commission acts on behalf of the people of California when providing public interest energy research program funding to California researchers. These researchers include small businesses, universities, California-based national laboratories, utilities, energy companies, and private research organizations. By selecting and coordinating research among these organizations, the Energy Commission maximizes the effectiveness of the program.

Successes and benefits of Energy Commission natural gas research investments include tangible technology advancements and improvements that help California meet energy policy goals. For example, research provided the justification that led to pipe insulation requirements for the state's energy standards for homes. These standards take effect on January 1, 2014, and the change will save California ratepayers an estimated 8.2 million therms per year over a six-year period and reduce ratepayer bills by nearly $7.9 million every year.

The Energy Commission is committed to being a responsible steward of its natural gas research and development investments. This stewardship is illustrated by the Energy Commission's adherence to both statutory direction and the state's energy policies. For example, energy efficiency research projects address a number of state policies and goals, including the California Public Utilities Commission's (CPUC) *Energy Efficiency Strategic Plan* and the California Energy Commission's *Integrated Energy Policy Report;* Governor Brown's Clean Energy Jobs Plan; and Assembly Bill 758 (Skinner, Chapter 470, Statutes of 2009), which seeks to increase energy efficiency in existing buildings.

Renewable energy research helps bring clean alternatives to conventional natural gas resources to commercialization. These research projects address a number of renewable energy generation and greenhouse gas reduction goals, including the Global Warming Solutions Act of 2006 (Núñez, Chapter 488, Statutes of 2006). California's Renewable Portfolio Standard (as mandated by Senate Bill 1078 [Sher, Chapter 516, Statutes of 2002] and Senate Bill 107 [Simitian, Chapter 464, Statutes of 2006]) are among the most progressive in the United States. These standards were expanded by Senate Bill X1-2 (Simitian, Chapter 1, Statutes of 2011, First

[1] Energy Information Agency. State Energy Data System. www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_sum/html/sum_btu_totcb.html

Extraordinary Session), which aims for 33 percent of energy generation to be provided by renewable resources by 2020.

Natural gas transportation research promotes advancements in renewable natural gas production and natural gas vehicle technologies that will help California meet the Low Carbon Fuel Standard (LCFS) goal of reducing the carbon intensity of California's transportation fuel mix by 10 percent, and the *State Alternative Fuels Plan*, which sets targets for alternative fuel usage in the state.

Projects funded with Energy Commission funding are consistent with the annual budget plans and policy objectives approved by the CPUC. Annual reports detailing the research, development, and demonstration activities approved in the budget plans are submitted by October 31 for each fiscal year.

This *Natural Gas Research and Development 2013 Annual Report* describes natural gas research, development, and demonstration projects from July 1, 2012 – June 30, 2013, as required by the CPUC Decision 04-08-010. The projects are listed in the appendix.

CHAPTER 1:
Introduction and Program Overview

The Role of Natural Gas Research and Development

California continues to rely on natural gas to meet many of its energy needs, including space heating, cooking, industrial processes, natural gas vehicles, and power plants. Roughly 90 percent of the natural gas supply in California comes from the southwestern United States, the Rocky Mountains, and Canada.[1] The remaining 10 percent is produced in-state, both offshore and onshore. The safe and efficient production, transportation, and use of this energy source are vitally important to California's economy, social vitality, environment, and clean energy future.

Recognizing the importance of natural gas as a critical energy resource for California, Assembly Bill 1002 (Wright, Chapter *93*2, Statues of 2000) directed the California Public Utilities Commission (CPUC) to impose a surcharge on all natural gas consumed in California. This surcharge is used to fund a range of public interest research and development (R&D) activities in the research areas of energy efficiency, renewable energy and advanced generation, and energy infrastructure. These activities are directed toward advancing science and developing technologies that increase natural gas end-use efficiencies, improve reliability, or reduce environmental impacts, which are not adequately addressed by competitive or regulated entities. The California Energy Commission has administered natural gas R&D in the public interest since 2005. The program has since been updated by Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006), which changed how the natural gas research funds are encumbered and managed.

The CPUC has established that the Energy Commission's natural gas R&D projects must:

- Focus on energy efficiency, renewable technologies, conservation and environmental issues.
- Support state energy policy.
- Offer a reasonable probability of providing benefits to the general public.
- Consider opportunities for collaboration and cofunding with other entities.

The *Natural Gas Research and Development 2013 Annual Report* submitted to CPUC is the eighth annual report, covering the 12-month period of fiscal year 2012-2013 (beginning on July 1, 2012, and ending June 30, 2013) to satisfy CPUC reporting requirements. [2]

---

1 California Energy Commission

2 California Public Utilities Commission, Decision 04-08-010 (August, 19, 2004), http://docs.cpuc.ca.gov/PUBLISHED/FINALDECISION/39314.html.

Report Structure

The *Natural Gas Research and Development 2013 Annual Report* describes the past year's research accomplishments, including new, ongoing, and completed projects, as well as their benefits to stakeholders and California ratepayers. Chapter 1 introduces the Energy Commission's natural gas R&D and describes how it complies with and informs state policy objectives, using a wide array of stakeholders who guide the development of research strategies and initiatives. Chapter 2 describes research program areas and Energy Commission-funded projects completed in 2012 that show evidence of measureable energy savings or other benefits. Chapter 3 highlights research activities that are ongoing and are expected to demonstrate future energy savings. Chapter 4 details the methods used by Energy Commission staff to assess statewide ratepayer benefits to the program. Appendix A lists the natural gas-funded R&D projects that were awarded in FY 2012-13.

Natural Gas Research Meets Policy Objectives

As California's primary energy policy agency, the Energy Commission is the author of the state's guiding energy policy document, the *Integrated Energy Policy Report (IEPR)*. Working closely with a variety of energy-related state and local agencies and stakeholders throughout the development process, the IEPR evaluates overall supply and demand trends for electricity, natural gas, and transportation fuels in California, as well as issues associated with energy infrastructure, efficiency, reliability, and cost. This comprehensive outlook ensures that consistent information is used among all parties involved in developing energy policy decisions affecting the state. Based on these assessments, the IEPR recommends energy policies to the Governor. The *2012 Integrated Energy Policy Report Update* finds that California must continue to fund cutting-edge research, development, and demonstrations to produce the next generation of clean energy technologies. The Energy Commission funds natural gas research across a broad spectrum of areas including efficiency, renewable energy, advanced generation and storage technologies, energy-related environmental protection, transmission and distribution, and transportation technologies. These R&D efforts align with the recommended IEPR energy policies.

Research Guides State Energy Policy

The Energy Commission's natural gas R&D work fills a critical role. Frequently, the results of this work are incorporated into the state's energy efficiency policies and standards. For example, Energy Commission research provided the justification that led to pipe insulation requirements for the *2013 Residential Building Energy Efficiency Standards*[3]. These requirements were adopted by the Energy Commission in May 2012 and take effect on January 1, 2014. This change will save California ratepayers an estimated 8.2 million therms per year over a six-year period and reduce ratepayer bills by about $7.9 million every year. Additional benefits include reduced greenhouse gas emissions, reduction in water use, and greater customer satisfaction.

---

3 *2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings* (May 2012) http://www.energy.ca.gov/2012publications/CEC-400-2012-004/CEC-400-2012-004-CMF-REV.pdf.

Numerous projects, including those highlighted in this report, will provide lasting benefits to California's economy and natural gas ratepayers.

Table 1 summarizes some of the state's major energy policies and standards. The Energy Commission's funding decisions are designed to meet these policy goals without sacrificing safety or reliability.

Table 1: Select Policy Goals for California's Energy Future

Policy or Standard	Goal
Governor Brown's Clean Energy Jobs Plan	California should produce 20,000 new megawatts (MW) of renewable electricity by 2020, 12,000 MW of distributed energy, and 6,500 MW from combined heat and power (CHP).
California's Loading Order, from the California *Energy Action Plan*	Prioritizes Energy Commission's research investments: first in energy efficiency and demand response; second, in renewable energy and distributed generation; and finally, in clean fossil fuel sources and infrastructure improvements.
Executive Order B-18-12 – Greening State Buildings	Calls for efficiency improvements in new or renovated state buildings larger than 10,000 square feet; sets zero-net-energy (ZNE) and greenhouse gas (GHG) reduction goals.
Integrated Energy Policy Report	The Energy Commission's biennial energy forecasting and assessment report recommends policies to foster the development of energy efficiency, renewable energy, and more.
Assembly Bill 32 (2006) − The California Global Warming Solutions Act	Requires the state to reduce greenhouse gas emissions to or below 1990 levels by 2020.
CPUC *Long-Term Energy Efficiency Strategic Plan*	Sets efficiency goals, including zero-net-energy goals for new homes by 2020 and for new commercial buildings by 2030.
Senate Bill X1 2 (2011) – The Renewables Portfolio Standard	Requires all electricity retailers to meet 33% of their retail sales with renewable energy by 2020.
Senate Bill 1250 (2006)	Contains provisions for appropriating to specified entities to fund cost-effective energy efficiency and conservation activities and public interest research and development not adequately provided by the competitive and regulated markets.
The State Alternative Fuels Plan	Recommends actions to meet alternative fuel goals and sets a goal of 26% of the fuels coming from alternative sources by 2022.

Policy or Standard	Goal
Executive Order S-01-07 Low Carbon Fuel Standard (LCFS)	Sets goal to reduce carbon intensity of the state's fuels by 10 % by 2020.

Source: California Energy Commission

Natural Gas Research Investment Plan − Developing the Research Portfolio

The natural gas energy research funding plan and portfolio follows the state's "loading order" of energy resources, which was established in 2003 in the state's first *Energy Action Plan*[4]. Since energy efficiency is the least expensive, most reliable and environmentally responsible strategy, the loading order identifies energy efficiency and demand response systems as the preferred means of meeting the state's growing energy needs. These are followed by renewable energy resources, distributed generation, combined heat and power applications, and finally by clean and efficient fossil-fired generation. This loading order has been instrumental in California's leadership as a clean energy innovator.

Budget Plan Summary

In March 2012, the Energy Commission provided to the CPUC *The Natural Gas Research, Development, and Demonstration Program Proposed Program Plan and Funding Request for Fiscal Year 2012-13*. This proposed plan established the direction and budget for natural gas research and development. In June 2012, the CPUC approved the plan and authorized the Energy Commission to administer $24 million for R&D natural gas projects over a two-year funding period. The Energy Commission expects to fully encumber all funds for new awards by June 30, 2014.

Administration expenses for FY 2012-2013 were allocated for program staffing. The Energy Commission currently has 14 staff positions funded with natural gas funds. The FY 2012-13 Natural Gas R&D Budget Plan Summary by research area is displayed in Table 2.

4 *State of California Energy Action Plan (May 2003)* http://www.energy.ca.gov/energy_action_plan/.

Table 2: FY 2012-13 Natural Gas R&D Budget Plan Summary

Program Areas	Approved Budget
Energy Efficiency	$8 million
Buildings End-Use Energy Efficiency	
Industrial, Agriculture, and Water Efficiency	
Renewable Energy and Advanced Generation	$4 million
Energy Infrastructure	
Natural Gas Pipeline Integrity	$1 million
Energy-Related Environmental Research	$3 million
Natural Gas-Related Transportation	$4 million
Energy Innovations Small Grants Program	$1.5 million
Program Administration	$2.5 million
TOTAL	**$24 million**

Source: California Energy Commission

Response to CPUC Resolution G-3484

On June 27, 2013, the CPUC considered and approved the Energy Commission's Natural Gas R&D program request for budget year 13/14. Along with the approval outlined in CPUC Resolution G-3484, the CPUC required that new information be included in the Annual Report to highlight two points outlined below.

1. The resolution requires the Energy Commission to explain its process for funding the PIER Natural Gas R&D program in cases where the CPUC authorizes less than what the Energy Commission proposed in its budgets.

The Energy Commission acknowledges that the CPUC retains the authority to approve the full amount of funds requested in the annual Natural Gas R&D Budget Plan or to reduce that amount if the CPUC believes that a lesser amount is in the ratepayers' interest. If in future years the CPUC decides to authorize less than $24 million, the Energy Commission will proportionally reduce the requested transfers from the Gas Consumption Surcharge Fund by that amount. Below is the detailed process the Energy Commission would follow:

- The Energy Commission submits a proposed budget as part of the annual State Budget process in the fall of each year for consideration in the next year's Governor's budget. Included in the budget request is up to $24 million in proposed PIER Natural Gas funding.
- The Energy Commission submits a proposed PIER Natural Gas Budget plan to the CPUC by the following March 31st of each year for the CPUC's consideration. Typically the CPUC decides on the request by June 30th.
- The state budget is approved by the Legislature and signed by the Governor.

- Depending on the outcome of the steps above, the Energy Commission requests that the CPUC transfer the funds in four equal payments on October 1, January 1, April 1, and July 1 of the appropriate year.

If the annual natural gas budget plan submitted to the CPUC in March of each year is approved for the requested $24M, then the Energy Commission will request the transfer of $6M from the *CPUC Gas Consumption Surcharge Fund* in quarterly payments on the dates identified above. Once transferred those funds are placed in the Energy Commission's *Public Interest Research Development & Demonstration, Natural Gas Subaccount*.

If during its review of the proposed natural gas budget plan, the CPUC determines that it does not want to fund an element of the proposed budget (for example, only approve $22M of the $24M requested in the budget plan), then the CEC would request from the CPUC four equal payments of $5.5M that fiscal year instead of the maximum possible of $6M. Therefore, the CEC will only request one fourth of the amount approved by the CPUC and adopted in their resolution for any given year be transferred into the *Public Interest Research Development & Demonstration, Natural Gas Subaccount*.

2. The resolution requires that the Energy Commission give an accounting of unspent PIER Natural Gas R&D funds in each future year proposed budget, beginning with the proposed budget for Fiscal Year 2014-2015.
    - When the Energy Commission receives PIER Natural Gas funds on an annual basis, the Energy Commission is authorized in the approved state budget a two year encumbrance period and an additional four year liquidation period for these funds. This means that the Energy Commission must place these funds on an encumbering agreement (grant, contract, purchase order, etc.) by June 30th the second year of the funds to ensure they are encumbered within the approved two year period. Once these funds are placed in an agreement, the Energy Commission has another four years to complete the actions in the agreement (for a total of six years) and the funds liquidate on June 30th the sixth year after the funds were authorized.
    - Unspent funds will normally result from three conditions:
        - First is when funds are not encumbered by June 30th by the second year after the funds were authorized. In this case, the funds would remain in the *Public Interest Research Development & Demonstration, Natural Gas Subaccount*. These unspent funds are not authorized to be used for any other purpose.
        - Second is when the funds were encumbered on an agreement prior to June 30th of the second year after the funds were authorized, but not spent by our contractor/recipient within the required six year life of the funds. In this case, the Energy Commission would disencumber the unspent funds from the agreement (grant, contract, purchase order, etc.) and the funds would remain

in the *Public Interest Research Development & Demonstration, Natural Gas Subaccount.* These unspent funds are not authorized to be used for any other purpose.

- The final example is when the contractor/recipient for a grant, contract or other agreement at the end of the agreement has unspent funds when the agreement is closed out or terminated. Again, the Energy Commission would disencumber the unspent funds from the agreement (grant, contract, purchase order, etc.) and the funds would remain in the *Public Interest Research Development & Demonstration, Natural Gas Subaccount.* These unspent funds are not authorized to be used for any other purpose.

The Energy Commission will provide the requested information on unspent funds in the Fiscal 2014-2015 proposed budget report and notification to the CPUC will continue on an annual basis until otherwise directed by the CPUC. The CPUC will provide directions as to how they desire these unspent funds to be managed: (1) used in future budget cycles as an offset to future transfers from the *CPUC Gas Consumption Surcharge Fund*, (2) added to a specific PIER Natural Gas Annual Budget requests as an increase in the budget over the normal annual base budget funds or (3) returned to the *CPUC Gas Consumption Surcharge Fund upon the Energy Commission receiving state budget authority.*

Program Updates

Stakeholder Outreach − Avoiding Research Duplication

In creating the investment plan and developing its research portfolio, the Energy Commission receives input from experts in energy research, including the state's investor-owned gas utilities, state and federal agencies, and other interested parties. Periodically, the Energy Commission, in conjunction with the CPUC, holds workshops to explore research initiatives across all natural gas technical subject areas in consideration for the upcoming fiscal year. Bringing together utilities, researchers, manufacturers, end users, and policy makers from state and federal agencies, such as the California Air Resources Board, these and other Energy Commission workshops help avoid research duplication, generate new research ideas, and establish the best research industry practices.

For example, the Energy Commission initiated an informal partnership with the United States Department of Energy's (U.S. DOE) Advanced Research Projects Agency – Energy (ARPA-E) program to maximize coordination of funding opportunities. ARPA-E supports development and deployment of transformational energy technologies and systems.

The Energy Commission is also a major participant in the West Coast Regional Carbon Sequestration Partnership (WESTCARB). Established in 2003 by the U.S. DOE, WESTCARB works collaboratively with public agencies, private industry, nonprofits, and universities to identify and validate the best regional opportunities for reducing carbon dioxide (CO_2) emissions in the atmosphere. Working to identify the major stationary sources of CO_2 such as

power plants, oil refineries, and cement plants, WESTCARB seeks technologies that can separate or capture these emissions.

The Energy Commission also supports and participates in the activities of the Emerging Technologies Coordinating Council (ETCC). The ETCC provides a forum for members to meet and exchange information on energy efficiency research and to provide a path for promising technologies to the marketplace.

Careful oversight of public funds signals to investors that California is a great place to invest in energy development.

Contracts and Solicitation Updates: Enhancing Investments for California

In recent years, the Energy Commission expanded its efforts to contract with California-based entities (CBEs)[5], using competitive selection processes, ensuring that most natural gas funds are spent in California. These improvements were made in response to feedback from stakeholders and policy makers and to increase the program's effectiveness as a generator of California energy investments.

A CBE is a corporation or other business form organized for the transaction of business that either:

- Has its headquarters in California AND manufactures in California the product that is the subject of the award.
- Has an office for the transaction of business in California and substantially manufactures the product or substantially performs the research within California that is the subject of the award.

Natural gas R&D funds are typically awarded competitively through grants or solicitations. A competitive solicitation is a public request for proposals to provide services, a specified product, and/or solve a defined problem under an agreement. The procedures for competitive solicitations follow the requirements under the *State Contracting Manual*, State Public Contracts Code, Public Resources Code, and other laws and regulations, such as civil service restrictions, prevailing wages, and the California Environmental Quality Act.

Energy Commission proposal scoring criteria favor proposals with low overhead and general and administrative costs.

5 Public Resources Code Section 25620.5 (h) and (i).

Planned Funding Opportunities

Natural Gas Energy R&D Program's Anticipated Funding Opportunities

The Energy Commission will continue to implement R&D consistent with the CPUC-approved budget plans for fiscal years 2012-13 and 2013-14. Information about potential upcoming funding opportunities will be posted to http://www.energy.ca.gov/contracts/_upcoming.html as it becomes available. Information posted on this page is subject to change.

Funding opportunities in the form of solicitations are public requests for proposals to provide services, a specified product, and/or solve a defined problem under contractual agreement. The Energy Commission uses Program Opportunity Notices (PON) for grants and Request for Proposals (RFP) for contracts.

The following Table 3 lists upcoming natural gas R&D funding opportunities for fiscal year 2013-14. To receive an e-mail when solicitations are released, interested parties can subscribe to the list server located at http://www.energy.ca.gov/research/.

Table 3: Natural Gas R&D Funding Opportunities, Fiscal Year 2013-14

Tentative Schedule	Potential Natural Gas Focus Area and Solicitation Name	Summary of Proposed Natural Gas Research
Summer/Fall 2013	**Energy Efficiency: Industrial Research** Emerging Technologies Demonstration Grant Program (ETDG III-Natural Gas)	Potential funding of research projects that reduce natural gas use and increase the energy efficiency of industrial process
Fall 2013	**Energy Efficiency: Building Energy Efficiency Research** Natural Gas Building Technology Grant Program	Potential funding of the following research projects that reduce natural gas use and improve public health: Building Innovation Technologies • Space heating • Commercial cooking • Water heating • Zero-net-energy (ZNE) integration Energy Efficiency Related Indoor Environmental Quality
	Renewable Energy: • Advanced	Potential funding of the following research projects that reduce natural gas:

Tentative Schedule	Potential Natural Gas Focus Area and Solicitation Name	Summary of Proposed Natural Gas Research
	Generation and Energy-related Environmental Research • Localized Efficient and Advanced Power and Heat Systems (LEAPS)	• Improving efficiency and operational flexibility, reducing cost and emissions, and increasing use of renewable and alternative fuels in combined heat and power in industrial, commercial and residential applications. • Development and demonstration of distributed generation/combined heat and power (DG/CHP) systems for associated gas from field oil and gas production. • Reducing emissions from the direct use of biogas/biomethane and addressing potential operational issues associated with use of low heating value gas, and postcombustion technologies.
	Transportation: Advanced Natural Gas/Electric Hybrid Research and Development	Potential funding of the following research projects: • Research and development of advanced natural gas/electric hybrid concepts for medium- and heavy-duty vehicles with a goal to improve fuel efficiency and energy savings. The research projects are expected to reduce natural gas usage by using battery power to minimize emissions, idle, and low-load engine operation.
	Energy Innovations Small Grant Program:	Potential funding of up to $95,000 for hardware projects and up to $50,000 for modeling projects to individuals, small businesses, nonprofits, and academic institutions to conduct research that establishes the feasibility of innovative energy concepts.
Winter 2013	**Energy Technology Systems:** Natural Gas Pipeline Safety Natural Gas Pipeline Safety and Damage Prevention Grant	Potential funding of the following research projects: • Conduct research and demonstrations projects that shorten the path to market for technologies that find problems and prevent damage to the pipeline infrastructure.
	Transportation: Development and	Potential funding of the following research projects: • Develop and demonstrate the manufacturing

Tentative Schedule	Potential Natural Gas Focus Area and Solicitation Name	Summary of Proposed Natural Gas Research
	Demonstration of Advanced Natural Gas Onboard Storage Tanks	viability and performance of on-board advanced natural gas fuel tanks. The research projects are expected to demonstrate low-pressure, lightweight absorption tanks, thus lowering costs associated with natural gas storage and increasing the vehicle operating range.

Source: California Energy Commission

CHAPTER 2:
Completed Project Highlights

Project Overview and Highlights for Research Yielding Significant Results

This section highlights natural gas R&D projects that were completed in fiscal year 2012-13 and are producing significant results toward resolving California's energy issues. The following are the major funding areas.

Energy Efficiency Research – Projects in this research area seek to improve the energy efficiency of homes and businesses, industrial processes, agricultural operations, water and wastewater systems, and data centers. As the state's population continues to grow, demand for energy will increase, and improving energy efficiencies is California's most important strategy for reducing energy use and cost, greenhouse gas emissions and other harmful impacts associated with the inefficient uses of energy. California's building efficiency standards are updated every three years and continue to improve as technologies advance. Industries strive to keep operating costs low while maintaining environmentally clean and energy-efficient operations. Agricultural operations such as food processing plants benefit from advanced processing techniques and heat recovery technologies.

Renewable Energy Research – R&D promotes renewable energy and advanced generation technologies such as improvements in industrial heat recovery, customer-side solar thermal applications, renewable alternatives to natural gas fuels, and combined heat and power (CHP) systems.

Energy Infrastructure Research – The safety and security of the natural gas system infrastructure are important priorities for California. In its Resolution G-3484 approving the *Natural Gas Research, Development, and Demonstration Program Proposed Program Plan and Funding Request for Fiscal Year 2013-14*, the CPUC emphasized the importance of this area by approving $2.5 million in funding for natural gas pipeline safety and development.

Energy Innovations Small Grant (EISG) Program– These grants are in the amount of up to $95,000 for hardware projects and $75,000 for modeling projects. The grants are available to businesses, nonprofit organizations, national laboratories, individuals, and academic institutions to research establishing the feasibility of innovative natural gas energy concepts. Designed to support the early development of promising new technologies, EISG projects must a) be completed within 12 months, b) target energy efficiency, renewable energy, or energy infrastructure, c) address a California energy problem, and d) provide potential benefits to California natural gas ratepayers for energy efficiency research.

Energy Efficiency Research

Buildings End-Use Energy Efficiency R&D Projects

Food service in California represents a significant commercial energy savings opportunity. Commercial kitchens consume five times more energy per square foot than other types of

commercial spaces. New research developed and promoted high-efficiency gas-fired cooking and water heating appliances.

The Project: Advanced Foodservice Appliances for California Restaurants

The Issue: In California, commercial food service employs 1.5 million people in more than 62,000 establishments.[6] This large industry uses five times more energy per square foot than typical commercial spaces, offering a significant energy savings opportunity. The technology efficiency baseline for commercial food service appliances is very low, with appliance efficiencies in the 20 to 30 percent range and actual cooking time as low as 5 to 10 percent of a restaurant's operating hours. High cooking temperatures and always-on control systems are the rule. Of the 800,000 commercial cooking appliances installed and operating in California, roughly 70 percent are powered by natural gas with few, but increasing, ENERGY STAR® equipment options.

Most water heaters installed in food service facilities meet just the minimum efficiency standard. The potential to reduce energy use for water heating in commercial operations is significant – estimated at 50 million to 100 million therms per year with effective market transformation. This results in approximately 20 to 40 percent reduction of natural gas used by the commercial food service sector for water heating.

The Research: This project was to investigate technology efficiency improvement opportunities in six key product areas affecting the commercial food service marketplace. In most cases, prototype units were constructed and then tested in the laboratory and then in actual restaurants. For example, wok ranges are essential for preparing Asian-style cuisine. The cooking versatility of a wok makes it the workhorse of most Asian-style restaurants. The wok range can be used for frying, poaching, braising, searing, and steaming. Most wok ranges also require constant surface cooling with fresh water to prevent operator burns and structural warping from the high temperatures. These ranges typically use a gallon of water per minute to keep surfaces cool. Most wok ranges in the marketplace today employ conventional ring-style burners. Burner wells or chambers are cylinders that extend from the rim upon which the wok pan sits to the opening in the bottom of the appliance frame where the burner is positioned. They are designed to insulate and direct the flame to the bottom of the wok pan. The range frame construction is stainless steel, which can warp when exposed to the high temperatures used when operating the wok range. A water inlet is provided to actively cool the surfaces of the range while cooking.

The advanced wok prototype is equipped with improvements to these outdated designs; a Micron-Fiber Tech custom cylindrical mesh burner improved heat transfer from the burner to the wok pan, an ignition system was installed to eliminate the need for a standing pilot, and a ceramic burner chamber was installed to replace the hollow conventional burner well. This chamber focuses the heat toward the bottom of the wok pan and away from the stainless steel

6 National Restaurant Association.

structure of the range, reducing the reliance on cooling water for the wok frame. A prototype wok pan with heat-sink fins attached to its bottom was also developed to enhance heat transfer.

Other examples of improvements include an advanced burner that employs an automatic shut-off and reignition device that is triggered by the detection of cookware, pilotless ignition systems, improved cooking vessels that use aluminum fin channels to increase the surface area exposed to the burner flame, improved door seals and exhaust flues, combustion blowers, sensors, or control system improvements.

The project included strong links to the California commercial food service market through the project team members, five manufacturers (Garland, Lincoln, Lang, Montague, and Royal Range), and two California utilities (Pacific Gas and Electric [PG&E] and Southern California Gas Company). Table 3 lists commercial food service appliances developed and tested. The five-year market penetration rate estimates in Table 3 were based on previous market introductions that PG&E's Food Science and Technology Center and the Gas Technology Institute have done over the past 30 years and on input from the manufacturers and demonstration sites.

Table 3: Food Service Appliance Improvements Developed and Results[7]

Appliance Type	Units in Operation in CA Food Service Facilities	Energy Savings Over Conventional Equipment*	Estimated Percent Penetration in 5 Years	Estimated Annual Natural Gas Savings (million therms)
Conveyor Oven	10,900	38%	50%	4.1
Convection Oven	68,000	40%	35%	4.0
Range	41,500	33%	50%	2.7
Wok	39,000	40%	30%	5.7
Underfired Charbroiler	42,000	23%	50%	6.7

This research concluded that there is a clear opportunity to advance the state of the art of five major types of cooking equipment by developing more efficient designs that maintain the functionality required by operators. The convection oven is available in the market. A lidded

7 Gas Technology Institute, *Advanced Foodservice Appliances for California Restaurants,* Draft Final Report to the California Energy Commission, June 2013.

underfire charbroiler, an efficient wok, and a conveyor oven should be commercially available in 2014. The range may be available in late 2014 or early 2015.

Chefs that have used the new energy efficient equipment were satisfied and in some cases noted higher production capacity. Chef Kevin Gin from the Bridges Restaurant and Bar in Danville, California, felt that "[b]y replacing our original convection oven with the new Garland ENERGY STAR convection oven, we increased our production capacity while gaining more consistency in our quality of product. Both important wins for us and with the behind-the-scenes energy savings from the previous dinosaur we had, the question is why we didn't make a change sooner? It is imperative that business owners and chefs become more aware of what these food service research projects have to offer if they want to stay in business and grow more quality products."[8]

Furthermore, for water heating in commercial kitchens, the research concludes that tank-type water heaters operating in systems with no recirculation offered the best system delivery efficiency. Adding insulation to the distribution system increased the system delivery efficiency and delivery temperature at the fixtures, and this could be considered for a future energy efficiency standard.

The Benefits: Assuming a five-year market penetration rate, equipment improvements recommended in this research could result in annual savings of 23.2 million therms with a greenhouse gas reduction of 123,000 metric tons. Significant energy cost reductions help California's food service industries stay competitive, and the early adoption of advanced, efficient technologies often confers an additional competitive advantage. Advancements in this area, and their subsequent adoption by the market, also help drive industry attention and investment in further technological improvements.[9]

8 Per e-mail conversation between Energy Commission staff and Chef Kevin Gin, August 2013.

9 Assume conversion factor of 0.0053 metric tons/therm.

Figure 1: Efficient Wok Range

The new efficient wok range increases efficiency from 13 to 35 percent and eliminates the use of a water cooling system.

Source: Gas Technology Institute
Agreement Number: 500-09-044 Contractor: Gas Technology Institute
Project Cost: $1,985,502.00 Co-funding: $ 917,875 Project Term: June 30, 2010 to July15, 2013

The Project: Residential Water Heating Program

The Issue: Water heating is the most significant residential end use for natural gas in California. Natural gas is used to heat water in nearly 90 percent of homes statewide and represents 49 percent of the average annual natural gas household consumption of 354 therms.[10] The 12.3 million California households that use natural gas water heaters annually consume 2,111 million therms.[11] An average California household could see its annual natural gas water heating consumption drop by up to 35 percent using an advanced water heater combined with an improved distribution piping system.

The Research: The research sought to reduce natural gas consumption for residential water heating in California. The following summarizes the research and the results:

- Developed an integrated hot water generation and distribution system analysis tool for water heater performance and hot water distribution performance. This new, integrated tool will help designers and engineers develop a fully integrated water heater tank and distribution system model for homes and result in more efficiently designed systems.
- Developed design guide and best practices manual for efficient water heating equipment and piping system for use by designers, engineers, and homeowners to

10 *2009 California Residential Appliance Saturation Survey (RASS).*

11 Energy Information Administration (EIA).

maximize the efficiency of hot water systems in single-family homes. The guide includes basic building and distribution design, hot water load reduction strategies, equipment and control installation, commissioning requirements to assure that all systems and components are functioning correctly, and occupant education.

- Contributed to updates of the Building Energy Efficiency Code (T-24, Part 6) for 2013 and provided recommendations for the 2016 revision for single-family hot water distribution design. These updates include new requirements for gas (or propane) water heater installations regarding proper electrical outlet, vent category, and condensate drain feature to promote the use of high-efficiency water heating equipment. The updates also included requirements for pipe insulation for all hot water distribution piping greater than or equal to ¾-inch diameter and from the water heater to the kitchen.
- Conducted laboratory evaluations, monitored field performance of water heating equipment and distribution piping, and surveyed consumer behavior and plumber distribution system installation practices. These evaluations could lead to future energy code changes or best practice recommendations. Examples include discouraging the practice of bundling PEX (high–density, cross-linked polyethylene) piping due to heat loss across the pipes. Plumber training is critical to optimize residential plumbing design.
- Developed advanced water heating system curricula for the plumbing trades and other building professionals. A series of nine in-state workshops, targeting the plumbing trades, homebuilding professionals, and local code enforcement officials, were hosted by Pacific Gas and Electric, San Diego Gas & Electric, and Southern California Gas. The workshops were provided by the International Association of Plumbing and Mechanical Officials and GreenPlumbers® USA, an innovative nonprofit venture based in California that trains plumbers to promote the benefits of energy efficiency and water-saving technologies.

The Benefits: Based on calculations by Lawrence Berkeley National Laboratory for new home construction from 2009-2025[12], the findings from this research could result in a reduction of residential natural gas use for water heating by 3 to 4 percent. This reduction results in estimated cumulative savings of 86 million therms[13], along with significant reductions in emissions and hot water requirements. Investing in the work of identifying best practices and common-sense improvements within such a large and ubiquitous end use such as water heating does more than save energy: it improves industry and trade partner knowledge, helps bring

12 *Residential Water Heating Program – Facilitating the Market Transformation to Higher Efficiency Gas-Fired Water Heating* (December 2012).

13 *Residential Water Heating Program – Facilitating the Market Transformation to Higher Efficiency Gas-Fired Water Heating* (December 2012).

homeowners' attention to these issues and opportunities, and helps ensure that California's plumbing and building industries are prepared for a more efficient future, which will certainly require lower-energy water heating.

Figure 2: Behind-the-Scenes PEX Line

This image is an example of what PEX piping would look like when it has been unbundled. This shows the piping without insulation. Insulation should be added since PEX itself does not improve hot water insulation.

Source: Gas Technology Institute
Agreement Number: 500-08-060 Contractor: Gas Technology Institute
Project Cost: $1,984,761 Co-funding: $406,766 Project Term: June 30, 2009, to December 28, 2012.

The Project: Healthy Homes- Reducing the Hazards of Unvented Cooking

The Issue: Using natural gas cooking burners without adequate outdoor venting commonly leads to indoor air pollutant levels exceeding health-based standards. Cooking also emits pollutants, including fine particles. Current standards for kitchen exhaust ventilation, including range hoods, microwave range hoods, and other devices, do not address pollutant removal effectiveness. Many people do not understand the hazards associated with unvented cooking and that not using a range hood when cooking could be unhealthy. Builders, contractors, and consumers have inadequate information to select effective systems.

The Research: With support from the Energy Commission and cofunding from the U.S. Department of Energy, the U.S. Environmental Protection Agency, and the U.S. Department of Housing and Urban Development, Lawrence Berkeley National Laboratory (LBNL) conducted research on cooking-related pollutants and the use of range hoods to reduce exposures. This

research has measured emissions from cooking burners, measured and modeled pollutant concentrations in California homes, measured performance of range hoods in the lab and installed in homes, and conducted surveys to understand how frequently Californians cook using range hoods. Figure 3 below shows the distribution of highest 1-hour nitrogen dioxide (NO_2) concentrations in California homes that cook with natural gas, and Figure 4 shows the fraction of these homes with NO_2 concentrations exceeding the EPA standard for outdoor air. Nitrogen dioxide is a toxic gas, and long-term exposure could decrease lung function and increase the risk of respiratory symptoms. Range hood use reduces nitrogen dioxide concentrations and the number of homes exceeding ambient air quality standards. If all homes were equipped with effective range hoods that were used regularly, the number of homes exceeding air quality standards would drop dramatically. Measurements of pollutant levels in homes with gas cooking provide similar results as the simulation model.

The Benefits: These results exemplify the immense benefits of proactive, investigative investments in research. Sound, reliable data demonstrating the potential health impacts of an activity as common as cooking is important; the fact that these impacts are so clearly reduced by the simple, actionable step of switching on a fan is even more powerful. Millions of California families who cook with a gas stove stand to benefit from these findings and the improvements they call for.

These research projects focus on homes with natural gas appliances. Using the results from these projects, LBNL is leading an effort to create a standard test for pollutant capture effectiveness that would help consumers identify effective hoods. Improving awareness of this hazard and the available mitigation reduces the health burden of air pollutant exposure in homes. Results from these projects can be used to identify ventilation needs to protect public health in homes as the shift is made to a more energy-efficient, high-performance housing stock.

Figures 3 and 4: Indoor Air Quality Impacts of Range Hood Use

Using properly installed range hoods reduces exposure to toxic emissions from cooking.

Source: Lawrence Berkeley National Laboratory Contractor: Lawrence Berkeley National Laboratory Agreement Number: 500-09-049 Project Term: 08/09/2010 to 03/15/2015; 500-05-026 Project Term: April 3, 2006, to March 29, 2013; 500-08-061 Project Term: 06/30/2009 to 03/29/2013. Project Cost: $1,000,000 Co funding: $300,000.

Industrial, Agriculture, and Water Efficiency R&D Projects

The industrial, agriculture, and water (IAW) sectors in California annually use 30 percent of all natural gas consumed in the state and rely heavily on an affordable, reliable, and sustained energy supply. [14]This economic sector benefits from research that helps to reduce energy use and cost, helps to meet environmental challenges, copes with increasing energy demand, and accelerates the use of renewable resources.

The Project: Development of a Heat Recovery System for Corrosive Exhaust Gases From Industrial Furnaces

The Issue: An estimated 170,000 tons of aluminum is remelted annually in California. Aluminum remelters typically operate with a thermal efficiency of 30 percent. Without heat recovery, 60 percent of the energy from fuel is lost to the exhaust gas.

14 Natural gas data from http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SCA_a.htm.

In industrial processes with corrosive exhaust gases, such as aluminum smelting, heat recovery has not been an option for energy efficiency. Conventional heat recuperators have decreased longevity when they are used to recover heat from corrosive exhaust gases. Consequently, the recuperators are not commonly used for waste heat recovery from aluminum smelting and other industrial furnaces with corrosive exhaust gases. This results in high fuel use and costs, a lost opportunity to recover high temperature exhaust gas for use in industrial processes, increased greenhouse gas emissions, and other process-generated air pollutants.

The Research: The Gas Technology Institute (GTI), with cofunding from the Southern California Gas Company and Utilization Technology Development Company, developed and tested a pilot-scale prototype of a cost-effective gas guard regenerative (GGR) heat-recovery system. This heat-recovery system will enable aluminum remelt furnaces and other industrial processes to recover and reuse waste heat from corrosive furnace gases for increased efficiency, fuel cost savings, and reduced air pollution.

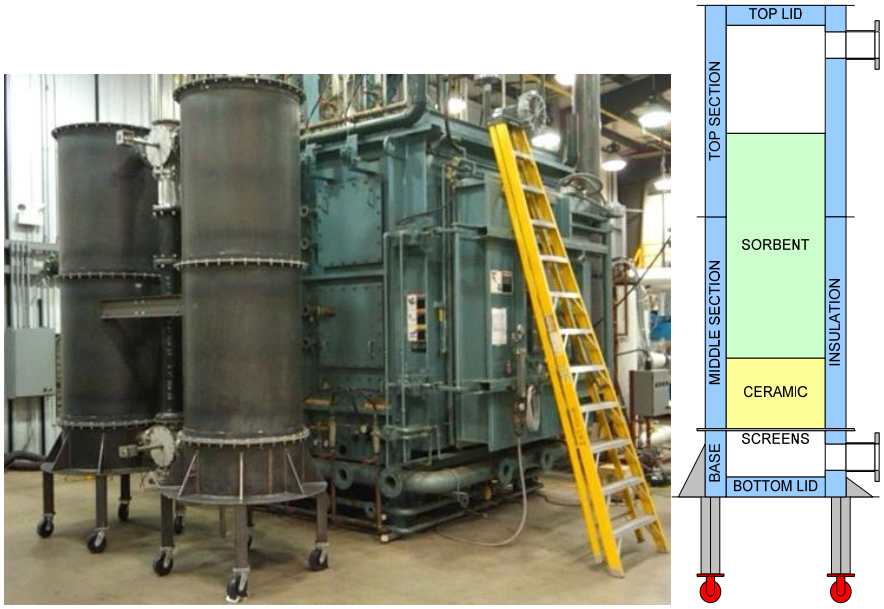
The Benefits: The low-emission, highly efficient system developed by this research stands to provide a wide range of benefits to California: a reduction in fuel costs and harmful pollutants will benefit not just the specific end-use industries, but their surrounding communities. Captured and reused waste heat is an emission-free substitute for costly purchased fuels or electricity. Based on the research results, the GGR technology was shown to recover 43 percent of the exhaust gas heat. This technology will increase furnace thermal efficiency by 10 percent, which results in a 23 percent fuel reduction. This technology can also be used by other industries with high-temperature corrosive furnace exhaust gases.[15] There are more than 30 aluminum remelters in California of varying sizes.[16] The potential annual natural gas savings from deploying this technology in all aluminum remelters in California is 2.4 million therms, with an estimated annual emissions reductions in carbon dioxide of 12,700 metric tons and oxides of nitrogen of 56,000 pounds.[17] However, many of the remelting furnaces are old and inefficient, and the incentives to upgrade the equipment are low. Assuming a 10 percent market penetration, this could reduce natural gas use in these California industries by 240,000 therms annually. Furthermore, this technology has the potential to reduce emissions of carbon dioxide and oxides of nitrogen annually by 1,270 metric tons [18]and 5,600 pounds, respectively, in California.

A furnace with a GGR system will reduce the concentration of hydrogen chloride in the hot exhaust gases by an estimated 96 percent and reduce greenhouse gas emissions by up to 28 percent. Given the relatively small footprint of the GGR heat recovery system, and the use of commercially available components, the projected installed cost is expected to be $225,000 to

15 http://www1.eere.energy.gov/manufacturing/intensiveprocesses/pdfs/waste_heat_recovery.pdf.
16 http://www.lightmetalage.com/producers.php#U.
17 GTI, Zelepouga, Serguei. 2013. White Paper Advanced Waste Heat Recovery with Hot Gas Clean Up Development of a Regenerative Heat Recovery System for Corrosive Exhaust Gases From Industrial Furnaces.
18 Conversion factor for greenhouse gas assumes 0.0053 metric tons per therm, per the California Air Resources Board.

$300,000 with an estimated simple payback of less than four years. Readily available, cost–inert, and sorbent media are used to reduce operating costs. Future research will determine the frequency of media replacements.

Figure 5: Picture and Cross-Sectional Diagram of the GGR



Heat Recovery Prototype Connected to Test Furnace with Vertical Reactors

Source: GTI
Agreement Number: 500-08-037 Contractor: Gas Technology Institute.
Project Cost: $490,000 Co-funding: $470,000 Project Term: May 28, 2009, to May 31, 2013

Renewable Energy and Advanced Generation R&D Projects

The goal of the Energy Commission's renewable and advanced generation energy research is to invest in research, development, and demonstration projects that accelerate the deployment and lower the cost of clean energy. These projects can help advance market adoption of innovative energy technologies, simplify interconnection, and support policies that enable sustainable renewable and advanced energy generation.

The Project: Integrated CHP Reduces Costs While Meeting Progressive Emission Standards

The Issue: The relatively simple design of gas turbines, low capital cost per kilowatt, and low maintenance requirements have led to their widespread use in combined heat and power (CHP) systems. In addition, using supplemental burners with gas turbines can improve the overall energy efficiency of the system by balancing the electricity and thermal output to match the energy demand of the facility. However, this method typically raises exhaust NO_x levels beyond the California Air Resources Board (ARB) 2007 standards for distributed generation, unless a costly and complicated catalytic flue gas treatment system, such as selective catalytic reduction (SCR), is added. Using SCR can increase the capital cost by 10-25 percent, thus limiting the further adoption of CHP systems, especially for facilities in the 10 MW or less range.

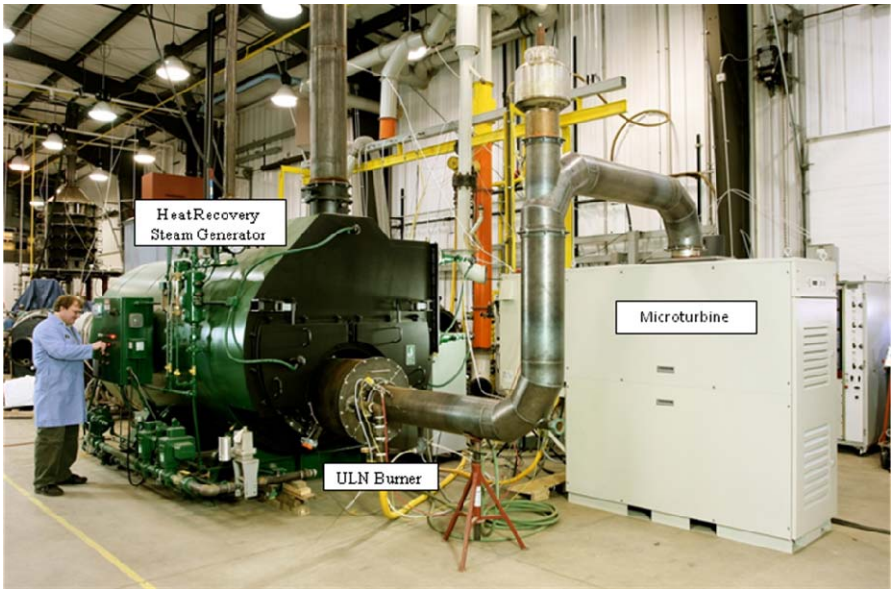
The Research: Researchers developed and demonstrated a system that combines a commercially available microturbine and boiler with a state-of-the art supplemental burner that recovers the waste heat of the microturbine. The key innovation for this project, a supplemental ultra-low-NO_x (ULN) burner, can fire natural gas along with the microturbine exhaust gas and meet the California emissions limits without using catalytic post-combustion treatment. The design uses staged combustion with engineered internal recirculation that exposes NO_x and NO_x precursors to a low-temperature zone. The system was successfully tested at the Gas Technology Institute's laboratory in Illinois and then installed and demonstrated at Inland Empire Foods in Riverside, California, a legume processing plant. The demonstration host site is very interested in the technology and in using progressive, clean energy practices and expects to use the technology to support extending the processing hours at its plant. Doing so will take full advantage of the efficiency and lower fuel costs of the system. The host site expects to recover its installation costs in roughly two years.

Operating under full-load conditions at the host site, NO_x, carbon monoxide (CO), and total hydrocarbons (THC) emissions were reduced by 45 percent, 97 percent, and 78 percent, respectively, with an overall system efficiency of 82-84 percent, compared to a microturbine and boiler operating independently. Fuel usage also decreased significantly. Overall, the results confirmed that the system improves overall efficiency, meets the ARB's 2007 emission standards, and provides a cost-effective microturbine CHP package.

The Benefits: This project supports California's policy goals by 1) demonstrating an environmentally sound CHP system with high overall efficiency that can meet the 2007 ARB emissions standard without selective catalytic reduction exhaust gas treatment; 2) supporting the mitigation and reduction of greenhouse gases emissions; 3) reducing capital cost of an integrated CHP system by 10 to 25 percent; 4) helping improve the competitiveness of California industry; and 5) improving the reliability of onsite power. Further research may extend the technology to the reciprocating engine exhaust.

The microturbine CHP package developed under this project employs off-the-shelf technology that can be manufactured locally. Its innovative supplemental burner features minimal burner pressure drop with no blower and augmentation air required. The system will be applicable to a variety of small to mid-sized commercial and industrial market segments, particularly sites in the 5-20 MW range that use boilers or absorption chillers. The efficiency drives of the system interest users nationwide, even where emissions standards are less strict. The developer estimates sales of up to 175 units nationwide in the next eight years and anticipates the sale of three in California in 2014. Sites in California expressing interest in the demonstration project are typical of the sites most likely to benefit from the CHP system. These California sites include a biodiesel refinery, a wire processor, a major hotel, a semiconductor manufacturer, and a food processor.

Figure 6: The Supplemental Burner System Installed



The system installed and operating at the test lab. Microturbine is on the right, boiler is on the left, and the ULN burner is in the center between the two. In an ideal configuration the distance between the boiler and the ULN and microturbine is short, thus keeping costs of ducting down.

Source: GTI
Agreement Number: PNG-07-006 Contractor: Gas Technology Institute.
Project Cost: $501,437 Co-funding: $673,283 Project Term: April 7, 2008, to March 31, 2013.

Energy Infrastructure Research

Natural Gas Pipeline Integrity R&D Project

These energy infrastructure research projects demonstrate natural gas pipeline integrity monitoring and inspection technologies that are past the "proof-of-concept" stage and are ready for demonstration in a real-world utility setting.

The Project: Natural Gas Pipeline Research – Best Monitoring Technology

The Issue: A complex network of natural gas pipelines, many of which travel under high population areas, transmits and distributes natural gas supplies throughout California. The pipelines have varying material composition and installation dates, making integrity management a difficult, laborious task. More than 10 million customers are connected to the pipeline infrastructure in California, and it is vital to deliver these services safely throughout the state. Various inspection technologies exist to monitor pipelines and detect flaws, though improvements are necessary to enhance the utility's ability to maintain a safe underground pipeline network.

The Research: In initiating the Energy Commission's natural gas pipeline safety research and development efforts, two contracts were awarded. Gas Technology Institute (GTI) sought to determine the best practices for monitoring pipeline assets. The research performed by GTI explored natural gas pipeline inspection technologies used throughout the world and identified

those not yet used in California. A catalogue of the best available technologies was created to help utilities select the appropriate tools to inspect and monitor pipelines, thus maintaining their operational safety. The final product was an implementation plan that identifies specific technologies and research efforts, and the actions necessary to implement them in a timely and cost-effective manner.

A complementary project with UC Berkeley's Center for Information Technology in the Interest of Society (CITRIS) is developing sensors to improve pipeline condition monitoring. Results are expected in the fall of 2014.

The Benefits: Identifying actionable improvements that will help keep California's gas pipelines safe is a crucial benefit of this research, as energy safety and reliability are among the most basic requirements for economic vitality, public health, and social well-being. The methods of inspecting and monitoring natural gas pipelines were assessed, and those that will provide the most benefits to California's natural gas pipeline integrity management practices were identified. The catalogue of available technologies provides operators a valuable reference in selecting the best inspection technology to use on the pipelines they manage. Through interaction with utility pipeline operators and California Public Utilities Commission staff, an implementation plan was developed to guide future Energy Commission efforts in pipeline safety.

Figure 11: Natural Gas Transmission Pipelines in California

Many miles of natural gas transmission pipelines run throughout California, often passing under highly populated areas.

Source: The Business Journals
Agreement Number: 500-10-050 Contractor: GTI
Project Cost: $480,000 Co-funding: $0 Project Term: June 30, 2011, to June 30, 2013.

Natural Gas-Related Transportation R&D Projects

Transportation research addresses several of the state's policy goals to reduce petroleum consumption, increase alternative fuel use, and reduce GHG emissions in California. Low-carbon transportation fuels, such as natural gas, have displaced roughly 2.14 billion gallons of gasoline and 77 million gasoline equivalents of diesel[19] since the 2011 implementation of the Low Carbon Fuel Standard. This displacement is equivalent to removing nearly 500,000 vehicles from California roads, or emission reductions equaling 2.8 million metric tons.

The Project: Lower–Cost, High-Performance and High-Efficiency Pilot-Ignited Directly Injected HD Natural Gas Engine)

19 http://news.ucdavis.edu/search/news_detail.lasso?id=10562.

The Issue: The use of natural gas in heavy-duty vehicle applications provides the opportunity to reduce dependence on foreign oil and lower greenhouse gas emissions to meet California's climate change goals, while substantially reducing fuel costs. Widespread adoption of an advanced natural gas combustion system that maintains the performance and efficiency of diesel engines has been hampered by the inability to achieve controllable auto-ignition combustion. Most natural gas engines replace the non-premixed auto-ignition of a diesel engine with a premixed, spark-ignition system to operate with natural gas. Using a throttle and spark plugs for ignition of premixed natural gas can significantly reduce efficiency compared to a diesel engine. To avoid this effect, natural gas can be injected directly into the cylinder at high pressure and burned in a predominantly non-premixed manner; however, a separate ignition source is required. Westport's system for high-pressure direct injection (HPDI) of natural gas provides a diesel pilot. The combustion of the diesel pilot is used to ignite a non-premixed natural gas jet. However, modifications were needed to make the engines using this technology competitive on a cost and performance basis with diesel counterparts.

The Research: The work completed through this project focused on improving Westport's existing HPDI natural gas engine technology, developed under a previously funded project, for the Westport HD 15L HPDI engine, which is used in heavy-duty freight trucks. The project used experimental engine testing and computational analysis on a Prototype-B 15L HPDI engine to provide a more robust, lower-cost, higher-performance, and higher-efficiency combustion system while still meeting California emission regulations. The key objective of this effort was to reduce cost, improve efficiency, and increase power while maintaining tailpipe emissions below regulated standards and decreasing sensitivity to variations in fuel quality. The key modifications from the original Westport HD 15 L engine are improved high-flow fuel injectors, a new piston design, a new virtual sensor for engine protection and fuel composition robustness, and new exhaust insulation for enhanced after-treatment performance.

The Benefits: At the completion of the project, a new Prototype-B engine was commissioned and fully calibrated.

The calibration of the Prototype-B engine was developed to achieve the program targets on the new hardware by adjusting the exhaust gas recirculation level, pilot quantity, injection parameters, and combustion phasing and air handling system parameters. When compared to the original engine, the Prototype-B engine was demonstrated to:

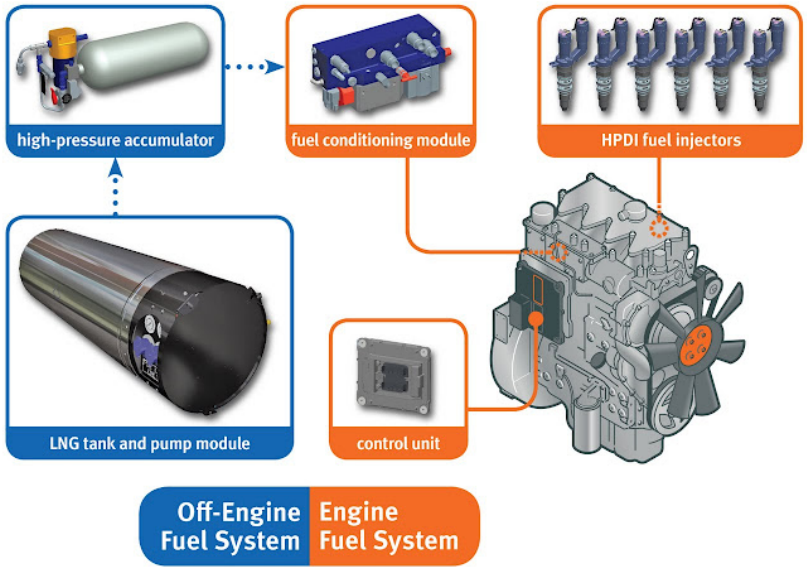
- Achieve a peak power of 520 horsepower (hp) compared to the Prototype-A 475 hp rating, with a 10 percent increase in torque across the evaluated engine torque curve.
- Emit tailpipe concentrations of NO_x, nonmethane hydrocarbons, particulate matter, and CO substantially below U.S. EPA 2010 emission standards at the 520 hp rating.
- Consume slightly less fuel (~0.5 percent) relative to the baseline Prototype-A engine at 520 hp.
- Operate on varying gas mixtures while maintaining optimum engine performance.
- Reduce pilot diesel fuel consumption by 20 percent.

Engine system modeling also indicates that additional efficiency improvements can be achieved and estimated to reduce fuel consumption by an additional 1.5 – 4 percent. When combined with the fuel consumption improvement noted above, it is expected that an efficiency improvement of 5 percent can be achieved over the base engine. Furthermore, hardware improvements and other fuel system cost reductions led to a 30 percent reduction in fuel system costs and a 5 percent reduction in after-treatment system costs.

The results demonstrate that the Prototype-B engine is a significant improvement over the current engine product, with lower cost, higher power, and more robustness to changes in fuel quality.

Engine emissions and efficiency were also maintained or improved.

Figure 12: Westport HPDI Fueling System Overview



Overview of the Westport 15L HPDI fueling system that was modified to improve performance and reduce costs of the engine

Source: Westport Power, Inc.
Agreement Number: PIR-08-045 Contractor: Westport Power, Inc.
Project Cost: $998,844 Co-funding: $998,844 Project Term: July 15, 2009, to December 31, 2012.

Energy Innovations Small Grants (EISG) Program R&D Projects

As stated in Chapter 2, this program is designed to establish the feasibility of innovative natural gas energy concepts. The Energy Innovations Small Grants Program helps promote private and federal investment in California's energy future.

The Project: Energy-Efficient Dehulling and Drying Methods for Walnuts

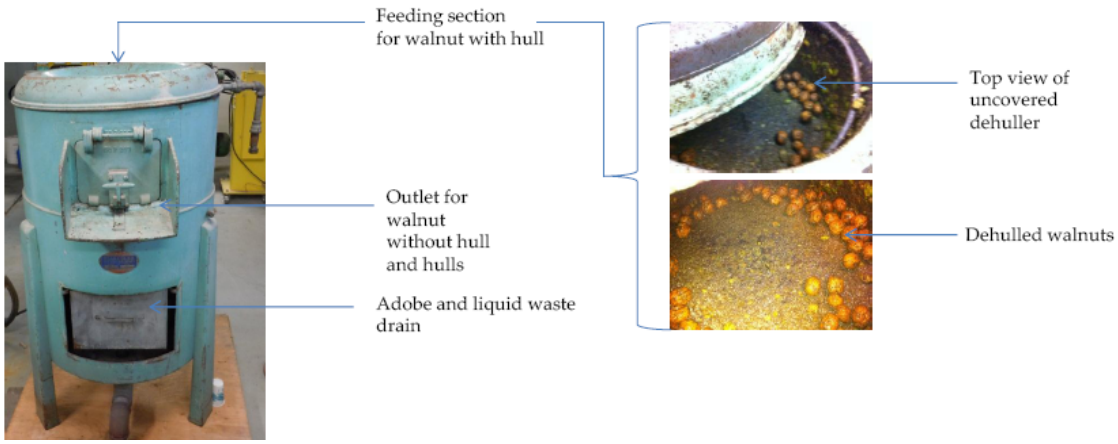
The Issue: Demand for California walnuts throughout the world has elevated walnuts to the fourth leading export from the state, valued at nearly $1 billion. Consisting of 5,300 walnut

growers and 55 processing centers, this industrial sector produces nearly 400,000 tons of walnuts each year. The California Walnut Board recognized that the most energy-intensive step is the walnut drying process. Because California produces 99 percent of the United States walnuts, reducing energy use and improving processing efficiency were identified as research priorities.

The Research: In this project, researchers developed and evaluated new walnut treatment approaches aimed at reducing energy use by the walnut industry and growers. The new approaches tested in-field dry hull removal, viability of near-infrared spectroscopic sorting of walnuts based on moisture content, and sequential infrared predrying and low temperature air drying. The research objective is to reduce energy use and production cost. Figure 13 illustrates the dry dehuller used in tests, one component of the multiple-step process. Other steps in the process include infrared sorting and predrying.

The Benefits: The primary benefit to ratepayers from this research is reduced energy costs. This technology has the potential to save California $2.9 million per year based on $0.94 per therm of natural gas and $1.95 per therm of propane. If fully developed and commercialized, the new technology could provide significant savings of natural gas and propane, as well as of transportation fuel for walnut hauling. The process may also be useful in other tree nut industries in California.

Figure 13: Dehuller



Illustrates the dry dehuller used in tests, one component of the multistep process. Other steps in the process include infrared sorting and predrying.

Source: Atungulu Proposal
Agreement Number: 500-98-014 Contractor: UC Davis, PI Griffiths Antungulu
Project Cost: $92,995 Co-funding: $56,973 Project Term: April 30, 2011, to March 31, 2012.

The Project: High-Efficiency Heat and Power System for CCHP Applications

The Issue: Combined cooling, heat, and power systems (CCHP) must be very efficient and low in cost to achieve commercialization. This is particularly the case with small modular gas turbine power systems, where power generation efficiencies are currently only about 30 percent.

The Research: The research team identified and defined the High Efficiency Heat and Power System (HEHPS), which uses turbine cooling, a heat exchanger, and working fluid innovations that can raise small gas turbine CCHP systems to power generation efficiencies of 45 percent. This approach will improve the heat recovery system to create an overall fuel-to-energy conversion efficiency of greater than 80 percent. The high power and overall conversion efficiency could make the system competitive with the grid and drive HEHPS deployment in California's small applications market. Implementation of HEHPS will increase the efficient use of natural gas.

The focus of this work was to show the potential of an innovative approach to improve microturbine-based CHP system efficiency and specific power, while simultaneously meeting and exceeding ARB 2007 emissions requirements, including the use of turbine cooling to allow higher turbine inlet temperatures.

The ultralow NO gas turbine combustor is now being applied in a stand-alone CHP system that uses novel heat exchangers to recover heat. In addition, the same gas turbine combustor is being used in a burner-based CHP system that adapts to existing and new boilers, water heaters, process heaters, and like equipment.

The Benefits: The primary benefit to California ratepayers from this research is a reduction in the cost of energy in California. These savings could total $210 million per year, with fuel savings of 12.6 million MMBtu/yr. In addition, environmental benefits could be substantial. Criteria pollutant reductions could be 445 tons per year, with greenhouse gas emissions reduced by 0.71 million tons per year. The EISG-funded technology is being developed by Altex and CMC engineering and is being commercialized by Leva Energy. Leva Energy received $250,000 from the San Joaquin Valley Air Pollution Control District's Technology Advancement Program to fabricate and install the technology at a designated site.

Figure 14: Power Burner

CHP system installed in Altex Test Facility 250 BoHP firetube boiler.

Source: John T. Kelly
Agreement Number: 500-98-014 Contractor: Altex Technologies
Project Cost: $ $94,915 Co-funding: $124,000 Project Term: August 2007 to February 2009.

Figure 15: Power Burner

Power burner tested at Altex installed in the Westin Hotel 250 BoHP Watertube boiler.

Source: John T. Kelly
Agreement Number: 500-98-014 Contractor: Altex Technologies
Project Cost: $ $94,915 Co-funding: $124,000 Project Term: August 2007 to February 2009.

The Project: A Pore-Flow Reactor for Landfill Gas Clean-Up

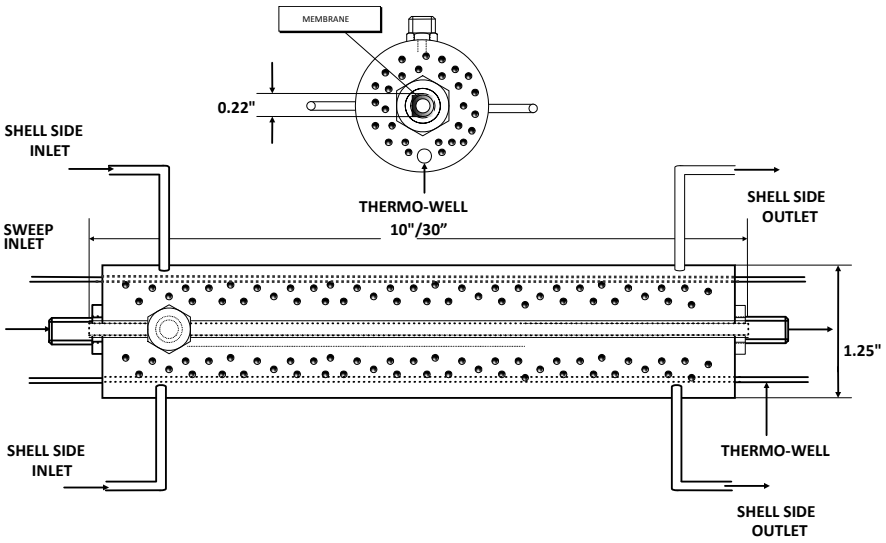
Issue: Landfill gas (LFG) is potentially a valuable renewable fuel because of the methane that it contains. But the presence of impurities in landfill gas presents challenges for effective use. Burning the gas for power generation or even flaring it, if these impurities are not removed, releases gases such as hydrogen chloride, sulfur dioxide, and so forth, which are toxic and harmful to both humans and the environment. Therefore, there is a strong incentive to develop effective technologies for removing the toxic compounds from landfill gas before it is used as a fuel. This research demonstrated the feasibility of using a proprietary reactor to remove toxic components from landfill gas. Successful removal of such contaminants could increase the use of landfill gas for renewable natural gas production or other applications in lieu of flaring or allowing the gas to escape into the atmosphere.

Project Description: The researchers successfully deposited a platinum catalyst on microporous membranes and used the membranes to treat a simulated landfill gas containing six representative nonmethane organic compounds. They demonstrated complete destruction of these compounds at temperatures ranging from 200° to 290° Celsius.

Project Benefits: The primary benefit to ratepayers from this research is the potential to reduce environmental impacts of the California energy supply and distribution system. If successfully scaled to commercial size, the reactor could remove nonmethane organic compounds from currently used and potential landfill gas supplies. This removal could reduce capital costs, operating costs, and potential discharge of toxic compounds. This technology could pave the way for economic recovery and use of presently unused landfill gas.

Dr. Theodore T. Tstotsis received additional funding from the National Science Foundation to further develop this technology in collaboration with Gas Control Environmental (GCE) and Media and Process Technology, Inc. Dr. Tstotsis has received funding from the Defense Threat Reduction Agency for the application of using the pore flow reactor concept for the destruction of chemical warfare agents. Total funding received is more than $1 million.

Figure 16: Membrane Module



The membrane module was used to test the effectiveness of different membranes using simulated landfill gas.

Source: Tsotsis Proposal
Agreement Number: 500-98-014 Contractor: USC
Project Cost: $95,000 Co-funding: $$6,645 Project Term: September 2007 to June 2009.

CHAPTER 3:
Ongoing Project Highlights

Project Overview of Prior Research Yielding Measurable Results

This chapter highlights key research projects that are ongoing or have recently been awarded and that show significant potential to yield future benefits. **Projects are organized by major research areas, which are summarized in Chapter 2.**

Energy Efficiency Research

Buildings End-Use Energy Efficiency R&D Projects

The Project: Advanced Envelope Systems for Factory-Built Homes

The Issue: Over the last few decades, California took steps to improve residential building performance, in part by adopting increasingly strict building standards under the state's Building Energy Efficiency Code (Title 24, Part 6). During these years, builders were introduced to innovative products and technologies and modified their building practices to reach higher energy standards. Research conducted by public and private agencies focused on creating building technologies that mainly applied to those built on site. The net effect was a nearly unprecedented rise in the level of residential efficiency, placing California at the forefront of national efforts to reduce energy use.

However, during the same period, the energy performance of manufactured homes changed only modestly for the following reasons:

- All manufactured homes produced in the nation conform to one set of preemptive standards, the Manufactured Housing Construction Safety Standards. These standards are enforced and maintained by the U.S. Department of Housing and Urban Development (HUD Code) and are less stringent than the state's Building Energy Efficiency Code. The HUD Code preempts state regulations. The following are examples of differences between the HUD Code and the state's Building Energy Efficiency Code (Title 24):
    - The HUD Code states that the envelope shall be designed and constructed to limit air infiltration to the living area of the home, but no maximum infiltration rates are specified. In addition, there are no maximum roof reflectance/emittance requirements.
    - Title 24 sets mandatory requirements for air infiltration rates at 0.3 cubic feet per square foot for fenestration (glazing) and exterior residential doors and for roof reflectivity and emittance.
- The added cost associated with greater energy efficiency is not well understood by either buyers or sellers of manufactured homes. As many homeowners of manufactured

housing are of limited means, an increase in price of only a few thousand dollars might result in not qualifying for a home loan. Manufacturers compete on price, and small differences in cost can affect a sale. Successful commercialization will depend upon demonstrating to all manufacturers that new approaches have little or no incremental cost to the building process, yet yield significant benefits to ratepayers.

The Research: The goal of this project is to improve the energy performance of factory-built housing in California. This goal will be achieved by:

- Improving wall and roof component designs to include energy efficiency and cost-effectiveness. The research includes adding foam to the fiberglass insulation in the walls and determining how this can be added to the manufacturing process without additional cost while improving the overall efficiency of the end product. Since it is part of the production process, labor and materials are easier to coordinate than for site-constructed buildings. These improvements in the quality and amount of insulation and better air tightness of the wall assembly result in less condensation, mold, and drafts, and improved overall in-home air quality. The net effect is manufactured homes that require smaller cooling systems, which can lower the overall capital cost while reducing annual energy costs.

- Involving key industry stakeholders in the development process to enable widespread market acceptance. The goal and expectation are that the new construction methods pioneered by this project will be standard practice in California within five years of completion. Several major California factory home builders are participating in this project.

The Benefits: More than 500,000 Californians live in manufactured homes, and it is estimated that sales are likely to average 10,000 homes annually.[20] This number compares to the roughly 490,700 site-built homes that were sold in California in 2012. With retail prices beginning at about $20,500, manufactured homes are among the more affordable types of home ownership. Compared to current factory home construction methods, the new designs from this research could result in estimated annual energy savings per home of 1,500 kilowatt hours (kWh) and 140 therms, resulting in an average annual energy cost reduction of $373.[21] The new, improved component technologies will allow developers to install smaller cooling equipment and reduce CO_2-equivalent emissions per home by an estimated 1.84 metric tons/year[22].

20 The Levy Partnership, Response to PON 12-503, "Advanced Envelope Systems for Factory Built Homes," December 2012.

21 Energy savings from Levy Partnership Response to PON 12-503 and assumes 0.15/kWh and $1.05/therm.

22 Assumes 0.0053 metric tons/therm and 0.00073 metric tons/kWh.

Figure 17: Prototype Wall Assembly for Factory-Built Homes

Future manufactured wall assemblies will have many advantages, including reduction in construction waste, tighter quality control, and the potential for significantly better energy performance.

Source: Levy Partnership, Inc.
Agreement Number: PIR-12-028 Contractor: Levy Partnership
Cost: $1,433,568 Co-funding: $299,781 Project Term: July 1, 2013, to April 30, 2016

Industrial, Agriculture, and Water Efficiency R&D Projects

The Project: Demonstration of Waste Heat Recovery

The Issue: California's industrial sector annually consumes about 3.37 billion therms (286.6 TBtu) of natural gas and 40,083 gigawatt hours (GWh) of electricity.[23] Of this, nearly 2.18 billion therms (218 TBtu/yr) of natural gas and 15,800 GWh of electricity are annually consumed in the chemicals, petroleum, glass/cement, and metals sectors.[24] A significant portion of this energy is used in relatively high-temperature furnaces generating exhaust gases above 800°F. Effective heat recovery technologies do not exist because of material limitations, low gas-to-gas-heat transfer rates, surface heat losses, gas leakages, and additional pressure losses. The heat recovery devices are able to recover only a portion of the heat in the exhaust gases and have difficulty meeting stringent furnace pressure control requirements. A significant opportunity exists to recover additional heat from industrial furnaces and generate electricity for onsite use, even from furnaces already equipped with heat recovery systems or have very stringent pressure control requirements.

---

23 Kavalec, C., Gorin, T., *California Energy Demand 2010-2020 Adopted Forecast.* California Energy Commission Report CEC-200-2009-012-CMF, December 2012.

24 California Energy Commission., *2009 Electricity and Natural Gas Consumption.* http://www.energy.ca.gov/research/iaw/industry.html, (conversion factor of 100,000 therms/Btu).

The Research: The emerging technology to be demonstrated effectively recovers waste heat in industrial exhaust gases above 800°F and converts it into power, while addressing many of the limitations of current technologies. The proposed technology is applicable to gas-fired furnaces with stacks exhausting to the outside, and those without stacks that exhaust directly inside the building. The technology is especially attractive for furnaces with demanding pressure controls and can be retrofitted without any furnace downtime.

The overall exhaust waste heat-to-electricity technology concept, which is the subject of this research project, combines a pressure-balance intake (PBI) connection[25] between a stackless furnace and a heat recovery water heater. A commercially available heat recovery water heater and an organic rankine cycle engine that has been demonstrated in many other hot water driven applications will be used. This project will demonstrate the technical and economic feasibility of the technology, and demonstrate the performance of the proprietary PBI connection and the organic rankine cycle engine[26] technology in an industrial setting.

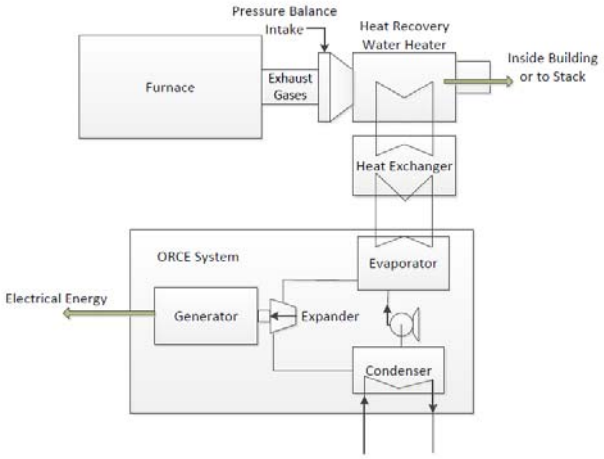
The Benefits: This project will benefit industrial processes with high-temperature furnace exhaust gases by recovering waste heat that can be used to produce electricity and reduce energy costs:

- The proprietary PBI component, which is critical for isolating furnace operation from any adverse impacts of the heat recovery systems, has undergone extensive design and modeling iterations by N2E (subcontractor) and has demonstrated very impressive results with more than 84 percent exhaust heat recovery. Researchers will demonstrate this system at the Shultz Steel Company's forging facility in South Gate, California, with the goal of recovering and converting to electricity at least 84 percent of the exhaust heat.
- This system can be installed as a retrofit without downtime or any adverse impacts on furnace performance. It can be used with both stack, such as those exhausting cleaned corrosive gas, and stackless furnaces. The applications for this technology are more broadly applicable than those for the corrosive waste gas project presented earlier.
- There is potential to achieve a financial return on investment in less than 4.5 years for the demonstration system and less than 3 years for commercial systems.

25 The pressure-balance intake device adds hot air from around the exhaust to increase heat recovery, increases exhaust gas flow rates and consequently increases heat transfer rates, and reduces the dew point, preventing condensation of corrosive components. .

26 In a rankine cycle, the working fluid is pumped to a boiler where it is evaporated and then passed through a turbine, where it is recondensed.

Figure 18: Proposed Exhaust Waste Heat System



This figure is a flow diagram shows the furnace, heat recovery system and the organic rankine cycle engine technology.

Source: Gas Technology Institute
Agreement Number: PIR-11-029 Contractor: Gas Technology Institute
Project Cost: $1,733,000 Co-funding: $850,000 Project Term: July 5, 2012, to March 31, 2015

The Project: Carbon Dioxide-Based Industrial Laundry Machine

The Issue: Commercial and industrial laundries have long been among the major water consumers in California, using millions of gallons of potable water each year. While the industry has implemented water efficiency measures, so far there have been no substitute solvents developed that offer environmental, performance, and cost benefits over water. The energy and environmental impacts of implementing laundry technologies that do not use water as a cleaning solvent are enormous. These benefits include reduced water consumption, decreased wastewater treatment and disposal costs, and more efficient use of energy due to the elimination of the textile drying step.

The Research: This project will develop and demonstrate an industrial-scale liquid/supercritical carbon-dioxide textile cleaning machine. The resulting industrial demonstration will document and validate:

- Real-world cleaning performance across different industrial/commercial textiles, fabrics, and surfactant formulations.
- Machine-operating specifications including utilities (for example, energy) consumption, cycle time; operability and workflow, component reliability; and sterilization/disinfecting capabilities.
- Benchmarking of all relevant performance/cost criteria versus incumbent water-based machines.

For this project, San Diego Gas & Electric and Southern California Edison have agreed to assist with the measurement and verification of energy savings, while the Los Angeles Department of Water and Power will help document water savings. The demonstration site will be the Aramark Cleanroom Service Facility in the Los Angeles area. To date, the novel machine has been installed and commissioned at the Aramark facility and is processing garments from the microelectronics industry. The other major cleanroom garment industry serviced at Aramark's Los Angeles facility is pharmaceuticals. The project team is conducting test runs with pharmaceutical garments, and initial test results are positive—garments passed all key performance indicators. Additional testing and process optimization will continue to achieve full validation for the use of CO_2Nexus's innovative carbon dioxide-based laundry machine for pharmaceutical garments. The project team is working on the energy and water measurement and verification phase of the project.

The Benefits: This technology is applicable to a wide variety of end users, including industrial laundries and textile cleaning, prisons, nursing homes, universities, military bases, and hotels. California has more than 8,000 such facilities. Assuming a 5 percent market penetration rate, this technology has the potential to save 264 GWh, 20 million therms, and more than 600 million gallons of water. In addition to having the capability of using recaptured CO_2 from industrial processes, such as ammonia or hydrogen production, this system reclaims more than 99 percent of the CO_2 used in each load cleaned. This factor, combined with the reduction of water use and the elimination of the drying cycle, results in a system with a lower carbon footprint compared to conventional water-based units.

Figure 19: CO2Nexus's Carbon-Dioxide Laundry Machine Installed at Aramark's Facility

This figure shows the wash basket on the left and the controls on the right.

Source: CO2Nexus, Inc.
Agreement Number: PIR-10-017 Contractor: CO2Nexus, Inc.
Project Cost: $396,200 Co-funding: $1,358,988 Project Term: October 10, 2010, to March 11, 2014.

Energy Infrastructure Research

Natural Gas Pipeline Integrity R&D Projects

The Project: Natural Gas Pipeline Research – Innovative Monitoring Technologies

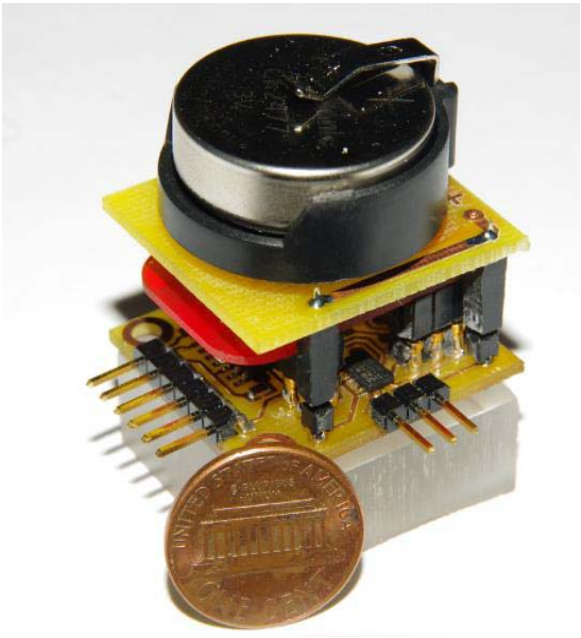
The Issue: The safety and security of the natural gas system infrastructure are important priorities for California, especially the prevention of catastrophic events on the natural gas pipeline network. To enhance the overall natural gas pipeline infrastructure, public interest research is needed to explore opportunities to apply new and emerging technologies related to pipeline integrity, operation, and safety. Direct pursuit of new technological solutions to improve pipeline safety is complementary to the work of GTI in assessing available technologies for inspection and integrity monitoring.

The Research: University of California, Berkeley, through its Center for Information Technology in the Interest of Society (CITRIS), is developing innovative monitoring technologies using micro-electro-mechanical systems (MEMS). The MEMS sensors provide two-way communications regarding pipeline operating conditions at a low cost. Use of MEMS enables sensing technologies that measure pipeline operational characteristics including pressure, flow rate, and vibrations due to external forces. Differences in flow rate and pressure measurements from multiple sensors can be used to detect the presence of leaks. Vibration

sensors will provide operators early indications that equipment may be encroaching on the pipeline right of way, allowing accidental excavation damage to be prevented. Construction of a pipeline sensor test bed allows the sensors under development to undergo testing in conditions found in utility pipelines. In building this resource, the designs will be evaluated and refined quickly before being deployed in utility-scale demonstrations. The test bed will also be used for accelerated lifetime testing to improve the reliability of the final design. The result will be a natural gas pipeline sensor design that has been proven in the field and is ready to transition from small-batch to large-scale manufacturing and commercialization.

The Benefits: The MEMS sensors will provide operators a more accurate picture of the pipeline condition through two-way communication of pipeline operational parameters. Researchers are developing a low-cost means of retractable installation to create a system to monitor the natural gas pipelines accurately. The low cost of the sensors will allow them to be deployed more frequently throughout the pipeline network, allowing potential problems to be identified and mitigated. Close coordination with utilities and members of the CPUC help guide development to ensure the final product meets the needs of pipeline operators. Deployment of these sensors will provide operators with tools to enhance the safety of the overall natural gas pipeline infrastructure.

Figure 20: Initial Sensor Package Form Factor



MEMS fabrication techniques allow multiple sensors to be integrated on a single chip at a low cost. The small size of the sensors will allow them to be easily installed in existing pipeline taps without affecting normal operations.

Source: CITRIS
Agreement Number: 500-10-044 Contractor: Regents of University of California Berkeley (CITRIS)
Project Cost: $478,457 Co-funding: $0 Project Term: June 30, 2011, to January 1, 2014.
Amendment 2 Pending – Additional $377,378, Contract end date – January 1, 2015

The Project: Public Safety and Gas Pipeline Vulnerability to Sea Water Intrusion

The Issue: California relies heavily on natural gas as a cleaner fuel of choice for the residential and commercial sectors, and for electricity generation. The 2010 San Bruno gas pipeline explosion was an important wakeup call that the safety of gas pipelines needs to be examined. Moreover, as sea level rises and storm surges increase with global warming, any existing structural issues to pipelines near coastal areas will be compounded by the potential intrusion of salt water. For example, interaction with sea water corrodes pipeline welds, which can lead to failure. Rising sea levels along the California coast will increase saltwater intrusion and inundate coastal areas, covering pipelines with salt ponds that would submerge lines never designed to withstand such permanent interaction.

In the Sacramento-San Joaquin Delta, earthen levees are used to prevent flooding on islands that are already below sea level and subsiding. As the sea level rises, the likelihood of levee failures will rise. This likelihood will increase the risk of inundation to the natural gas infrastructure (for example, natural gas pipelines and large underground storage units) in the Delta. Estimates project that it could take three months to pump water off islands after a levee failure. Long-term flooding, in turn, brings with it the risk of pipeline failure caused by the weight of the water covering the lines, as well as corrosion of the pipelines themselves.

The Research: This project is a comprehensive analysis of the vulnerability of gas pipelines to sea water intrusion in the San Francisco Bay Area and Sacramento-San Joaquin Delta regions. The figure below indicates areas subject to inundation from sea level rise and storm surges (dark blue) and the existing pipeline infrastructure in the Bay Area (colored lines). The project will include a statewide scoping study of pipeline vulnerability along the entire California coast; analyze various cost-based adaptation strategies for use in siting gas pipelines; and develop modeling tools for establishing environmental baselines and determining the environmental impacts of salt water intrusion on future pipelines. The research team will also develop useful risk assessment information, such as regional maps of gas pipeline locations. To date, detailed mapping of pipelines, along with flooding scenarios under various levels of sea level rise, have been completed for the Bay Area. Similar efforts are now underway for the Sacramento-San Joaquin Delta region and entire California coast.

The Benefits: The findings of this project will encourage adoption of more realistic environmental impact reports for future gas pipeline proposals based on risks from sea level rise, thus improving pipeline siting decisions. Currently, environmental impact reports do not include the impacts of sea water intrusion and their environmental consequences. This research would improve pipeline safety and reliability by including risk assessments of the potential for inundation. This assessment will also identify existing pipelines that are most at risk of inundation, thereby enabling utilities to proactively minimize future impacts. Preparation for sea level rise will also yield present benefits since levees in the Delta are currently vulnerable to failure. PG&E and other utilities are involved with this project, and results will be shared with them.

Figure 21: Bay Area Pipelines Threatened by Storm Surge and Sea Level Rise

Blue regions are subject to inundation by the end of the century.
Red lines indicate pipelines.

Source: John Radke.
Agreement Number: 500-11-016 Contractor: University of California, Berkeley.
Project Cost: $425,000 Co-funding: $0 Project Term: May 28, 2012, to June 30, 2014.

The Project: Wind Barriers to Reduce Wind Effects on Power Plant Air-Cooled Condensers

The Issue: A major environmental concern regarding electricity generation within California is the significant amount of water natural gas-fired power plants using wet cooling (cooling towers) will consume. A 500 megawatt (MW) gas-fired, combined-cycle power plant can consume up to 3 million gallons of water per day; the vast majority of this water use is for power plant cooling.

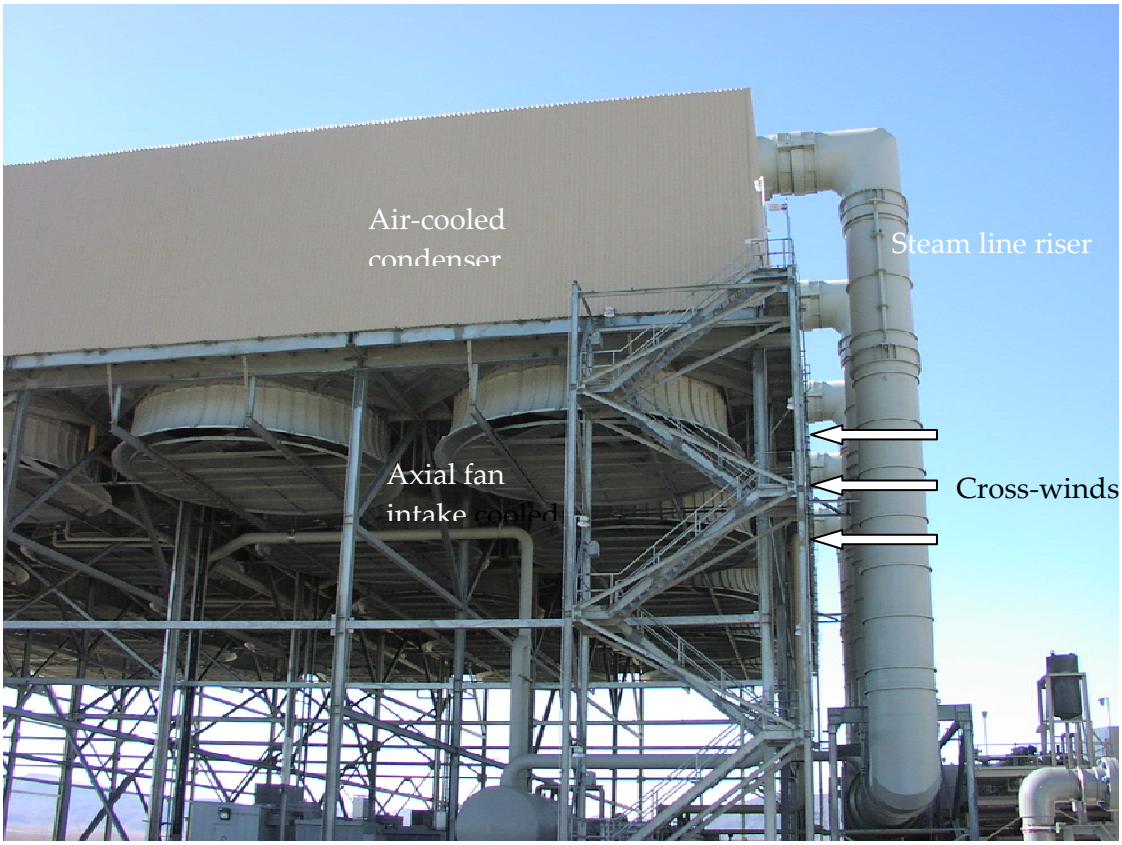
The use of air-cooled condensers, commonly referred to as *dry cooling*, eliminates this water demand since no water is used for heat rejection; however, the efficiency of this technology is reduced by high winds and ambient temperatures. For example, it has been shown that wind

speeds more than 20 mph on a hot day may reduce generation for a 500 MW combined-cycle power plant by 15 MW or more.

The Research: The use of wind screens or barriers sited beneath air-cooled condensers is the standard approach to reducing wind effects; however, research has shown that the use of wind screens at many power plants has little or no effect on wind patterns. It is estimated that careful design and siting of wind barriers can reduce these generation losses by 50 percent or more. This project is developing guidance for the specification, design, and siting of effective wind barriers for air-cooled condensers through the integrated use of field testing and high-resolution mathematical and physical modeling. Results from all three of the activities will be analyzed and combined to develop correlations of wind barrier effectiveness with barrier characteristics and wind conditions. Site access has been secured for the test site, and testing has begun on the instrumentation package that will be installed at the power plant by November 2013 to measure wind effects on air-cooled condensers. Physical and numerical modeling is progressing, with the initial wind tunnel testing to start shortly.

The Benefits: As more power plants in California and elsewhere are increasingly choosing air-cooled equipment to conserve water, it is imperative that a more rigorous and reliable approach to reducing wind effects be available.

Figure 22: Air-Cooled Condenser



View of an air-cooled condenser showing steam risers and axial fan intakes. Cross winds may create a low pressure zone beneath the fan intakes which stall the fans, reducing condenser efficiency. The wind walls being studied in this project would be located in the area between ground level and the fan housing.

Source: John Maulbetsch
Agreement Number: PIR-11-024 Contractor: John Maulbetsch
Project Cost: $749,577 Co-funding: $97,000 Project Term: June 25, 2012, to March 31, 2015.

The Project: Measurement and Mitigation of Methane Emissions From the Natural Gas Sector

The Issue: Methane emissions from California's energy infrastructure have been estimated to be 1.6 percent of consumption. However, new evidence suggests that these "fugitive emissions" may be greatly underestimated. Additionally, there is uncertainty regarding where the leaks are located within the natural gas system. Given the potency of methane as a greenhouse gas (GHG), fugitive emissions greatly reduce the benefits of natural gas as a cleaner fuel. A recent study estimates that fugitive emissions comprise 3 percent of natural gas, which would reduce the GHG benefits of using natural gas compared to coal from a 63 percent reduction to a 31 percent reduction in carbon emissions. These emissions will affect California's ability to meet its GHG targets. They also have safety implications since natural gas leaks can cause fires and explosions, and impact air quality and public health as methane reacts with sunlight and nitrogen oxides to form ground-level ozone, a pollutant that affects the respiratory system.

The Research: To address the problem of fugitive emissions, it is necessary to better understand how much methane is being emitted from the natural gas system and where in the system the leaks are located. The Energy Commission has awarded two ongoing studies designed to improve estimates of methane emissions and identify mitigation measures. The first will survey methane emissions from key subsectors of the natural gas system, including production and processing, transmission and distribution, and end uses in buildings. Air-based, land-based, and building-level measurements will be taken to quantify emissions at building, neighborhood, facility, and regional levels. It is expected that this work will identify the main sources of emissions from the natural gas system, but further work will be required to fully quantify total emissions. A complementary project is assessing options for lowering methane emissions by natural gas facilities. This project is exploring control options such as capture of gas currently released during compressor station blowdowns (when an offline station is depressurized by releasing gas). Alternate methods that reduce emissions will then be assessed.

The Benefits: Identifying and controlling methane leaks occurring in the natural gas system will generate public benefits in the areas of pipeline safety by reducing the risk of fires and explosions, regional air quality, public health, and reductions in the human-induced contribution to climate change through reduced greenhouse gas emissions and ozone levels. Areas with relatively high methane emissions and poor air quality, such as Los Angeles, will particularly benefit. Additionally, fewer leaks will decrease the amount of wasted gas, leading to a more efficient natural gas system. If the mitigation is significant enough, and low-cost control options are available, this technology can lower the cap-and-trade compliance cost for the natural gas industry and, in turn, reduce consumer utility bills.

Figure 23: Example of Roadway Survey of Methane Emissions. Spikes Indicate Methane Sources

Mobile measurements are used to identify the location of leaks in the natural gas system.

Source: Marc Fischer
Agreement Number: 500-11-027 Contractor: Lawrence Berkeley National Laboratory
Project Cost: $1,100,000 Co-funding: $0 Project Term: June 29, 2012, to March 31, 2015.
Agreement Number: 500-12-006 Contractor: University of California, Davis
Project Cost: $900,000 Co-funding: $0 Project Term: June 30, 2013, to June 30, 2015.

Natural Gas-Related Transportation R&D Projects

The Project: Natural Gas Engine Heavy-Duty Vehicles

The Issue: Of the major transportation sectors, medium- and heavy-duty vehicles account for roughly 20 percent of the total annual gasoline and diesel fuel consumption in California. Diesel exhaust emissions in congested urban areas contribute a significant portion of particulate matter (PM) and oxides of nitrogen (NO_x) air pollution, posing health risks to Californians and throughout the country. Large increases in domestic natural gas supplies have driven down the price, leading to renewed interest in natural gas as a transportation fuel for commercial vehicles. The economic opportunity for vehicles that consume large quantities of fuel has been limited by the lack of suitable heavy-duty natural gas engines. For the heavy-duty vehicle market, particularly the high-fuel-consuming Class 8 truck market, to adopt natural gas engine technologies, fleet operators need engines with comparable performance to diesel engines. As stated in the *Natural Gas Vehicle Research Roadmap*, "…there exists a lack of heavy-duty and off-

road engine sizes or capacity and that vehicle integration of new engines is a significant hurdle to greater natural gas vehicle availability and market penetration.[27]"

The Research: The National Renewable Energy Laboratory (NREL) is principal investigator for multiple design teams funded under the Natural Gas Engine and Vehicle Integration research project, including a project with Cummins Westport, Inc. (CWI), a global leader among natural gas engine manufacturers, to develop and optimize a spark-ignited 11.9 liter compressed natural gas (CNG) engine suitable for Class 8 applications such as heavy-duty freight trucks. CWI developed a high-efficiency, high-versatility, and low-emission natural gas engine to compete with diesel engines in the Class 8 sector. This engine was developed in two phases that consisted of an alpha-engine development, followed by the development of the beta version under this agreement. The U.S. Department of Energy, the South Coast Air Quality Management District, and the California Energy Commission jointly funded both the alpha and the beta versions of the CWI engine.

Following development, the engine has been integrated into a variety of vehicle chassis configurations for on-road testing under various driving conditions to validate the engine performance and chassis configurations for Class 8 applications. Demonstration trucks have completed about 2 million miles in 23 fleet operations by mid-2013 and availability of the ISX12 G has been announced by all of the major U.S. truck manufacturers.

Natural gas can be carried on the vehicle in either compressed or liquefied form (CNG or LNG, respectively). The ISX12 G can also run on renewable natural gas (RNG) made from biogas or landfill gas that has been upgraded to vehicle-fuel quality. A variety of CNG and LNG tank configurations are available to meet various driving range requirements.

The Benefits: The benefits of this research range from increased competitiveness of California's trucking industry to greater fuel economy and reduced air pollution. Commercial production and a limited release began in 2013 for the ISX12 G, and CWI has indicated that there is strong initial demand for this engine. The United Parcel Service has already placed an order for 700 vehicles that will use this engine, with nearly 60 of these vehicles being deployed in California over the next year. This engine will also be used in a variety of different vehicle applications in the heavy-duty vehicle market including, but not limited to, regional-haul drayage trucks and refuse collection trucks. Because of the flexibility of the engine and comparable performance to diesel counterparts, the benefits of emission reductions will be greater and more widespread as more operators and large fleets adopt this technology. This is particularly important in regions such as the South Coast Air Basin, where federal and California ambient air quality standards cannot be attained without significant emission reductions from heavy-duty vehicles, which account for nearly 80 percent of all emissions. Emission reductions for NO_x and other pollutants are achieved when compared to the diesel standard and can provide even further GHG emission reduction benefits with the expanded use of renewable natural gas.

27 *Natural Gas Vehicle Roadmap,* May 2008, page iii.

Figure 24: Heavy-Duty Natural Gas Truck

UPS is just one of the major freight companies making the switch to natural gas. The company just placed an order for 35 fleet trucks that will be powered by the Cummins Westport ISX12 G engine.

Source: www.etrucker.com.
Agreement Number: 500-10-053 Contractor: National Renewable Energy Laboratory.
Project Cost: $1,202,048 Co-funding: $2,059,442 Project Term: June 30, 2011, to March 31, 2015.

Highlights of Research Awarded in Fiscal Year 2012-13

In fiscal year 2012-13, $25.8 million in natural gas funding was awarded to begin 24 research projects**.** Table A-1 in Appendix A of this report lists the natural gas funded research projects expended from fiscal years 2010-11 and 2011-12 natural gas R&D budget plans. The projects highlighted below reflect a sampling of these efforts.

Energy Infrastructure Research

Natural Gas Pipeline Integrity R&D Projects

The Project: In-Line-Inspection Technologies: Accurately Locating and Measuring Pipeline Girth Welds

The Issue: America's natural gas pipeline network consists of more than 300,000 miles of large-diameter transmission lines, with the majority of that mileage having been constructed decades ago. As this massive underground infrastructure continues to degrade over time, it is vital to community and environmental safety that pipeline operators bolster integrity management

programs and obtain access to accurate, detailed data on the safety of these operational pipelines. Pipeline girth welds are particularly sensitive to ground movements that increase stress in these areas. The highly seismic nature of California increases the importance of determining the condition of girth welds to ensure system safety. New technology being developed by Diakont, an engineering and manufacturing firm with more than 20 years of experience in energy infrastructure assessment, provides the natural gas industry with a much-needed capability to perform critical inspections accurately and efficiently.

The Research: Diakont's new prototype multichannel scanning electromagnetic acoustic transducer (MS-EMAT) will perform comprehensive remote in-line inspection of gas pipeline girth welds. To date, there are no sensors available to internally inspect these highly sensitive regions. Diakont's MS-EMAT technology inspects for latent defects remaining from construction and operational defects. All of these types of defects worsen over time and reduce pipeline safety. The sensor will provide a comprehensive means of evaluating a pipeline girth weld and provide operators with very accurate data on the integrity of the infrastructure throughout the state.

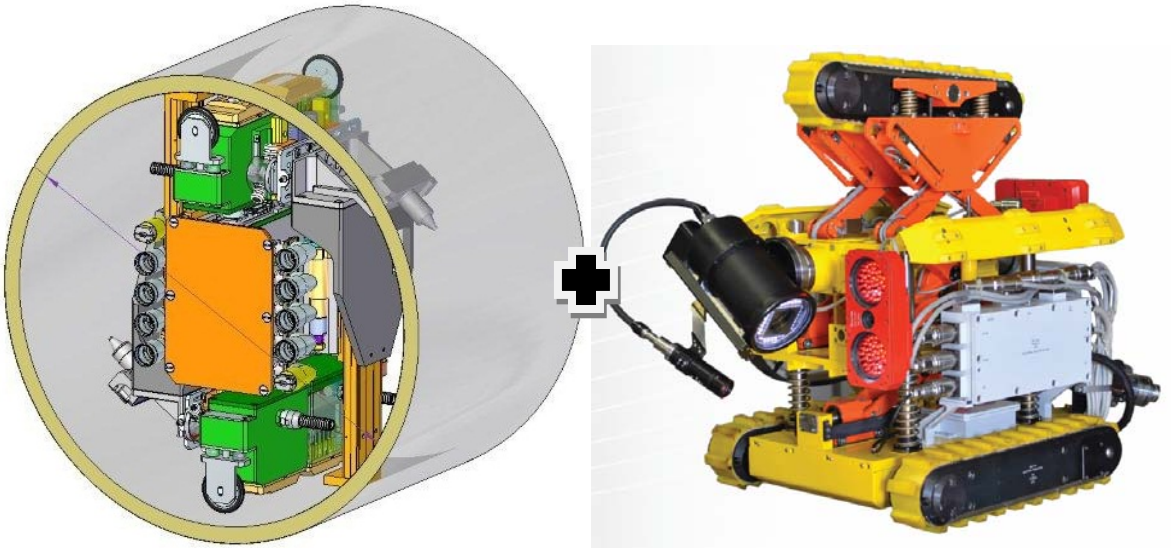
Diakont has already invested more than two years of research and development into expanding its existing EMAT technology to cover these specific weld areas. The sensor technology performance has already been validated by a third-party test lab. This project will complete the detailed development necessary to integrate the sensor on Diakont's existing RODIS pipeline robot and bring the technology to commercialization.

The Benefits: The MS-EMAT technology will replace current best practices for validating the integrity of pipeline girth welds, which typically rely on hydrostatic testing. Hydrostatic testing is a way in which pipelines can be tested for strength and leaks; however, it is criticized as an inspection method because of its inability to detect growing defects and its recognized potential to weaken or damage the pipeline. The MS-EMAT sensor will allow operators to accurately assess pipeline segments without putting its integrity at risk.

Bringing this product to the market will:

- Increase pipeline inspection capabilities available to the industry, which allow pipeline operators to make better-informed decisions about gas system pressure levels and maintenance.
- Prioritize repairs to concentrate efforts where needed most.
- Improve safety of lives and property.
- Reduce interruptions to service, thus decreasing operating costs and reducing ratepayer burden.
- Reduce risk of harm to the environment resulting from pipeline and hydro-test failures.

Figure 25: 3D Rendering of Diakont Prototype to Locate and Measure Gas Pipeline Welds



The MS-EMAT sensor module will be added to Diakont's pipeline crawlers to enable them to accurately locate and evaluate pipeline girth welds. By including multiple sensor devices on the crawler, inspectors can obtain increased information on the pipeline integrity while reducing associated time and costs.

Source: Diakont Advanced Technologies, Inc.
Agreement Number: PIR-12-009 Contractor: Diakont Advanced Technologies, Inc.
Project Cost: $1,000,000 Co-funding: $1,600,000 Project Term: July 1, 2013, to April 1, 2015.

The Project: Real-Time Active Pipeline Integrity Detection (RAPID)

The Issue: The primary materials used to construct natural gas pipelines are steel and plastic composites. Both of these materials are susceptible to premature aging and degradation. One of the leading causes of metallic pipeline failures is corrosion, whereas nonmetallic or composite pipelines are prone to cracking. There are a wide variety of nondestructive methods for locating areas of a pipeline that have suffered damage. However, when a damaged area is located, the pipe must be exposed and inspected to determine if the extent of the damage requires replacement. Currently, there is no reliable, built-in nondestructive method for determining if the damage is sufficient to affect operational safety. The existing methods require the pipeline to be shut down, resulting in a loss of revenue for the utility and potential outages for customers. In addition, the process of exposing the pipeline for inspection can result in further damage from excavation equipment.

The Research: Acellent Technologies, Inc., a structural engineering firm, will use structural health monitoring (SHM) technology to provide early warning of any physical damage to the pipeline so it can be assessed with minimal labor. The SHM technology consists of a network of distributed piezoelectric sensors or actuators embedded on a thin dielectric [28]film that can be applied to new or existing pipelines. These sensors act as miniature speakers and microphones

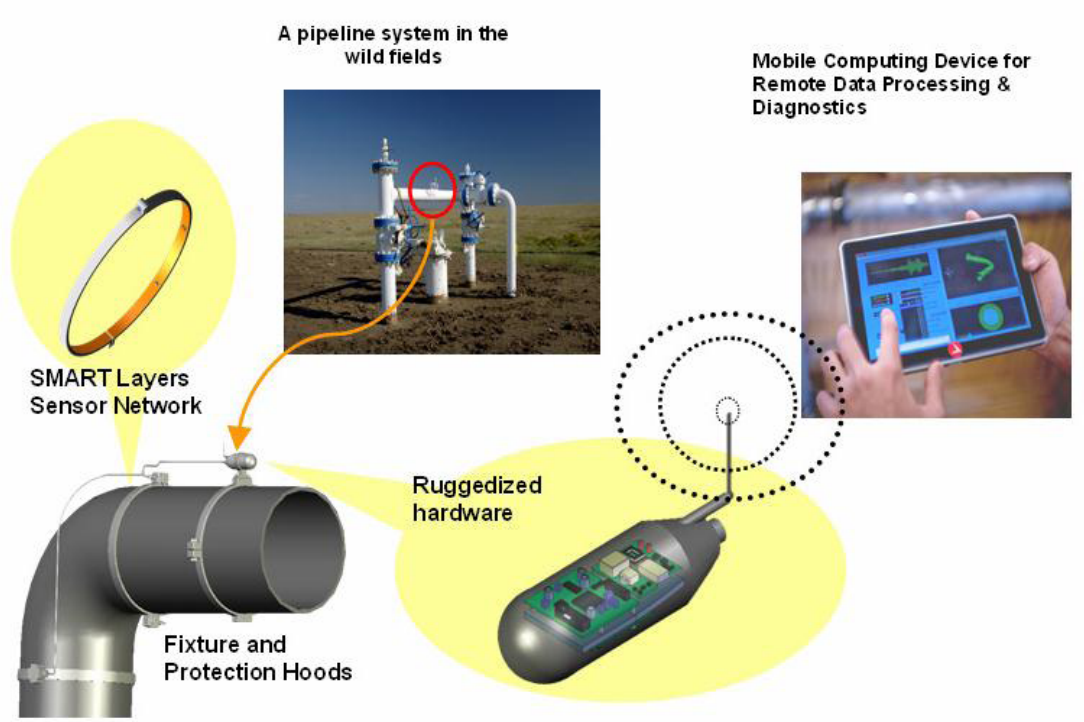
28 Dielectric material is an electrical insulator that can be polarized by an applied electric field.

that transmit waves between each other to establish a baseline frequency for a given application. Any changes to the received signals indicate a change in the material. Pipeline characteristics that can be measured include cracks, corrosion, and impacts from external sources. Modules of diagnostic data acquisition hardware will be placed at scheduled intervals along the pipeline to collect and analyze signals from the sensor layer and transmit them to the operator control room. The work performed will determine the optimal spacing of the sensors in bands around the pipeline girth, as well as the spacing between the bands to accurately monitor the pipeline. Accelerated lifetime testing will help to ensure the system can withstand exposure to elements in above- and below-ground installations.

Similar to the sensors being developed by CITRIS, the RAPID system will be used to obtain real-time information on pipeline structures, both accessible and inaccessible, while in service. However, the CITRIS sensors monitor pipeline operational characteristics, while the Acellent system will be used for monitoring pipeline integrity. Visible and invisible damage in the pipeline structures can be detected, which will provide operators with the location and magnitude of defects to facilitate repair. Following demonstration and development, the system will be marketed as a plug-and-play monitoring technology that can be adapted to meet a given operator's needs.

The Benefits: The RAPID system will provide operators with real-time continuous monitoring of pipeline integrity. The system will be able to provide data while the pipeline is in service and can eliminate revenue losses associated with shutting down a pipeline for inspection. The remote monitoring ability will also reduce labor costs associated with pipeline inspections. Early identification of defects to pipeline integrity can be assessed and monitored, allowing remedial strategies to be determined before the structural damage leads to a failure. Providing operators the ability to identify and continuously monitor threats to pipeline integrity will increase the safety and reliability of the natural gas transmission system in California.

Figure 26: Real-Time Continuous Monitoring of Pipeline Integrity



Bands of Acellent's SMART Layer sensors will be placed at regular intervals along the pipeline. Hardware will be housed in enclosures to protect the electronics from the elements while transmitting sensor data. The data from the sensors will be evaluated in the pipeline control room, or through use of mobile computers.

Source: Acellent Technologies, Inc.
Agreement Number: PIR-12-013 Contractor: Acellent Technologies, Inc.
Project Cost: $622,622 Co-funding: $0 Project Term: July 1, 2013, to September 30, 2015.

Energy-Related Environmental R&D Projects

The Project: Investigations of Potential Induced Seismicity Related to Geologic Carbon Dioxide Sequestration in California

The Issue: The *Scoping Plan* for the Global Warming Solutions Act of 2006 (AB 32)[29] specifically identifies the combustion of natural gas as a major source of greenhouse gas (GHG) emissions within California and identifies geologic carbon sequestration, or storage, as a strategy which holds significant potential to reduce these emissions. To effectively geologically sequester carbon dioxide (CO_2), the captured CO_2 gas is compressed, transported, and injected into an underground storage facility at a significant depth. The potential for induced seismicity, that is, an earthquake, to occur as a result of the injection of large amounts of CO_2 into the deep subsurface is well recognized, but not sufficiently researched. Seismic activity triggered by geologic carbon sequestration could cause leakage of the sequestered CO_2. In addition, recent public reaction to seismicity associated with fracking activities has highlighted the fact that induced earthquakes will remain a key public concern that must be addressed. Therefore, it is

29 *Climate Change Scoping Plan*, Pursuant to AB 32 *The California Global Warming Solutions Act of 2006.*

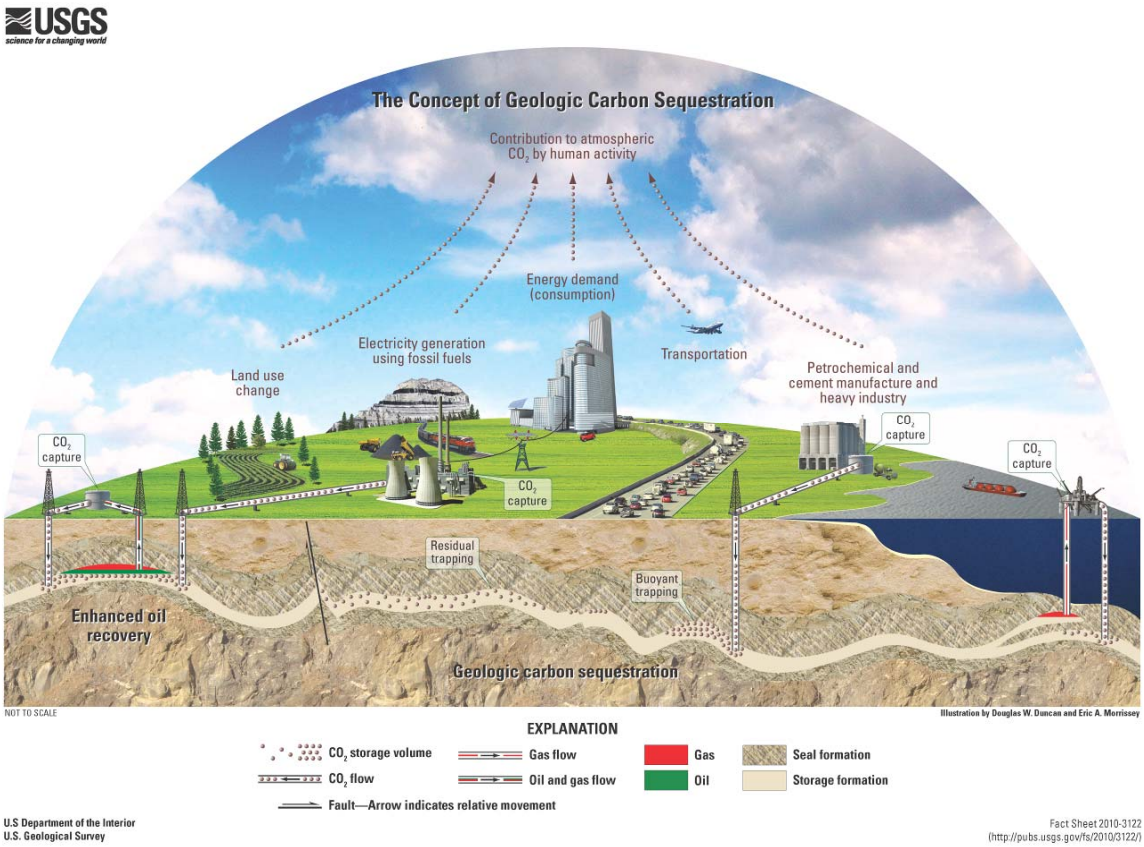
important to be able to predict how increased pore pressure may trigger seismic events resulting from CO_2 injection. It is unclear, however, what available data can be used to address these concerns as there are no relevant data sets specific to large-scale geologic carbon sequestration projects and no comprehensive analyses of the value and applicability of analog data.

The Research: This project will identify and assess existing data and rock core samples to determine if they can be used to address the problem of induced seismicity related to CO_2-injection by investigating potential seismic hazards related to geologic sequestration projects in California. The study will consist of two major components. The first phase involves assessing available data and rock samples to address the most pressing questions about the potential for geologic carbon sequestration to cause induced earthquakes or exacerbate damage from natural earthquakes. During the second phase, researchers will perform laboratory analyses and experiments on available samples and create computer simulations of potential events based on the data sets.

The project team will study seismic events associated with oil and gas injection and production, especially in areas where fault activity may have resulted in leakage, to improve the understanding of existing pressures and seismic responses to increased or decreased rock pore pressures. Core samples of relevant caprock, which is a layer of impervious rock, will also be assessed by measuring their fracture-related flow properties such as porosity, permeability, relative permeability, and capillary pressure (air-entry pressure) to understand how these formations in California will respond to increased pressures from sequestration activities. Finally, the team will obtain and evaluate information from well borings and other measurements that are available to better define the state of stress at specific sites. This information is necessary to constrain acceptable injection pressures better at carbon sequestration sites.

The Benefits: This research can advance understanding of the potential for and the severity of induced seismicity from geologic carbon sequestration, potentially a major barrier to commercial application of this greenhouse gas mitigation strategy. The project should provide preliminary risk assessment information relevant to informing development of seismic hazards regulations or permitting for geologic carbon sequestration projects in California. This information should also help reduce the costs and expedite the permitting of future geologic sequestration projects in California.

Figure 27: Predicting Long-Term Risk of Seismicity from CO_2 Sequestration



CO_2 captured at industrial and energy plants would be injected into an underground reservoir (labeled storage formation) beneath a caprock layer (labeled seal formation). The pressurized CO_2 could add stress to a seismic fault, potentially inducing an earthquake.

Source: Lawrence Berkeley National Laboratory.
Agreement Number: 500-12-010 Contractor: Lawrence Berkeley National Laboratory.
Project Cost: $575,423 Co-funding: $0 Project Term: June 19, 2013, to December 31, 2015.

Natural Gas-Related Transportation R&D Projects

The Project: Advanced 6.7 Liter Natural Gas Engine Development

The Issue: Market demand for natural gas-powered vehicles has significantly increased in recent years because of reduced emission and fuel cost savings benefits of these vehicles. However, the ability to sustain an expanding natural gas market is constrained by higher upfront vehicle costs and the lack of certain matching engine sizes and performance ratings. The variety of medium- and heavy-duty vehicles available with natural gas engines is not as broad as those with diesel engines, for which there is a comprehensive product line over a wide range of engine displacement, power and torque. Specifically, there are limited natural gas engines available that are suited for the Class 3 through 7 commercial truck markets, and due to this lack of suitable engines, the natural gas market share is small. Expanding the availability of engines suitable for a variety of vehicles in the Class 3 through 7 market segment will provide significant alternative fuel and emission reduction benefits.

The Research: The Gas Technology Institute (GTI), in conjunction with Cummins Westport Innovations (CWI), has begun developing an ultra-low-emission, high-performance, advanced 6.7 liter natural gas engine. The development of the CWI ISB6.7 G engine will meet the increasing demand for commercial vehicles that include medium-duty trucks, school buses, yard tractors, and street sweepers, powered by lower-cost, cleaner, and increasingly abundant natural gas. CWI will develop an alpha version of the engine, conduct field tests and customer demonstrations, obtain emission certification for U.S. EPA 2017 GHG emission standards, and proceed with the commercial launch of the new engine, expected to occur in 2015.

The Benefits: The CNG-fueled ISB6.7 G-powered vehicles are expected to reduce GHG emissions by 23 percent on a wells-to-wheels basis compared to similar diesel-powered vehicles. This engine will fill a gap in advanced engine availability for medium- and heavy-duty vehicle applications. A wider range of engine size offerings will allow more fleets to dedicate their operations to natural gas use and to take advantage of economies of scale throughout their operations. Operators of large truck fleets with a diverse number of vehicle types, such as local pickup and delivery trucks, have indicated to CWI their desire to transition entire operating depots and terminals from diesel to natural gas when natural gas engines become available for all the vehicles within their fleet. The goal is to provide these operators an engine with comparable performance capabilities that couples emission reduction benefits with fuel cost reductions.

Figure 28: Potential Vehicle Application for the New 6.7L Natural Gas Engine

Thomas Built Buses has publicly announced that it plans to use the 6.7L natural gas engine in its Type C Saf-T-Liner school bus chassis once the engine is commercially available in 2015.

Source: Thomas Built School Buses
Agreement Number: PIR-12-017 Contractor: Institute of Gas Technology dba Gas Technology Institute.
Project Cost: $1,000,000 Co-funding: $2,164,735 Project Term: August 2013 to December 31, 2014.

CHAPTER 4:
Benefits Assessment

Quantifying Benefits of Research

The following are the three major categories of benefits from the activities of the Natural Gas Energy R&D Program:

- **Economic benefits** consist primarily of lower energy costs and include job creation and economic development stimulated by reduced costs and other technological innovation.
- **Environmental benefits** include reduced impacts from global climate change, reduced public health risks related to indoor and outdoor air quality, and reduced impacts on the state's natural resources from energy generation and consumption.
- **Security benefits** include improvements to the reliability and safety of natural gas production and delivery and reductions in natural gas imports.

Benefits assessment involves the collection and evaluation of data throughout the stages of solicitation development, award, and project management. The following are typically collected from applicants of natural gas funding solicitations:

- How their proposed project meets a defined need in California, either through the development of technology for market adoption or the creation of information for policy makers and ratepayers.
- How the proposed project helps achieve the state energy policy goals and the technological innovation or information and tools the project will provide to meet those goals.
- Whether the proposed project would not occur without the expenditure of public dollars, or that it would otherwise not occur in time, manner, and place necessary to provide benefits to California ratepayers.

Benefits Methodology

At the conclusion of each natural gas R&D project, Energy Commission staff collects the information necessary to estimate the benefits to California ratepayers resulting from the research. The availability of data and firmness of the estimates vary with the research stage: technologies in the earliest stages of development typically provide limited quantitative data to report, while those close to commercialization or demonstration projects yield more data and better estimates on how the project will affect the market and environment. When available, these data are included with benefits assessments in the final report.

For a few selected, highly successful projects that demonstrate opportunities for substantial net benefits to California ratepayers, the Energy Commission conducts in-depth analyses to provide more precise and nuanced benefits assessments. In-depth analyses are documented in published reports.

In-depth analyses cannot be conducted for all projects. Nonetheless, the estimates of the net benefits from the single project presented in the sidebar are larger than the entire historical Energy Commission natural gas R&D funding of $162 million.[30]

For those projects that produce quantitative data but are not the subject of in-depth analysis, the Energy Commission staff estimated benefits as follows:

1. Define the size of the relevant California market for the adoption of the technology. Examples include the therms of natural gas consumption in an industry, the number of heavy-duty vehicles on the road, or the number of single-family homes to be constructed in future years. This value bounds the extent to which the technology could have a practical application in California.
2. Evaluate the benefits associated with the adoption of one representative unit of the technology. [31] Continuing with the above examples, these could include one combined heat and power (CHP) system, one heavy-duty vehicle, or one single-family home. Typically, because of the uncertainty of forecasting, benefits were

In-Depth Analysis

Project: "Water Heating and Hot Water Usage in California Homes"

Contractor: Lawrence Berkeley National Laboratory (LBNL) (Agreement #500-06-039R).

Research Results: The contractor studied the efficiency of residential hot water heaters and distribution systems. As a result of the knowledge gained from the project, updates were made to the 2008 revision cycle of Title 24, Part 6, of the California Building Energy Efficiency Standards. A cost-benefit analysis of the measure conducted by Energy Research and Development Division staff estimates that nearly 585 million therms will be saved in newly constructed single-family homes as a result of these measure over the period 2010 (when the standards take effect) and 2025. When the costs of compliance and financing are accounted for, the net benefits of these energy savings equate to roughly $167.2 million for that period. Beyond 2025, the net benefits continue will continue to grow.

30 Energy Commission.

31 It is often not possible to accurately evaluate the costs associated with the adoption of one representative unit of the technology. Even for demonstration projects—which typically involve technologies that are close to commercialization—the costs of designing, building, and testing a first-of-a-kind product may not provide substantial foresight of the cost of the technology. The economies of scale and learning curves inherent to commercial manufacture frequently reduce costs below those of first-of-a-kind research projects.

evaluated only over one year, such as the first year of adoption, the year of expected maximum market penetration, or a particular future year.

3. Apply a best estimate percentage to estimate the market adoption the technology upon commercialization. When the expected response of the market is difficult to assess, the default estimate is 1 percent. This value was chosen to be arbitrarily small, under the assumption that most technologies face highly competitive markets in which most consumers will continue to choose established products for the near future.

4. Calculate the combined benefits to California ratepayers that would result if the hypothesized market adoption of the technology were to be achieved.

The Energy Commission strives to communicate the results of this method cautiously since it is difficult to predict future market success or failure of any particular emerging technology. This method provides a conservative lower bound of the estimates. An example of the application of this method is Table B-1 of the *2012 Natural Gas Research, Development and Demonstration Report*.[32]

Benefits Analysis this Year

The method used to assess benefits cited in this report draws heavily upon past methodology described previously. It also encompasses recent innovations to increase the availability of data and quality of the quantitative analysis. Projects for which quantitative data are available comprise roughly only one-sixth of the projects that are the subject of this report. The absence of quantitative data for many projects reflects either their recent beginning or that the goal is to provide information and analysis, rather than develop a technology. In addition to the quantitative data collected and analyzed, qualitative data were also captured and are report reported:

- **Project Descriptions:** Tables B-2.1 through B-2.5 list all 108 active and completed Natural Gas projects the objectives of each project as part of their description.
- **Sorting by Primary Research Type**: The projects presented in Appendix B are grouped by the nature of the research, to enable readers to review related projects. The order of the tables is consistent with the Loading Order and other state energy policies:
    - Energy Efficiency
    - Renewable Energy & Advanced Generation
    - Natural Gas-Realted Environmentla Research
    - Natural Gas Related Transportation
    - Natural Gas Pipeline Integrity

32 CEC-500-2013-008. http://www.energy.ca.gov/2013publications/CEC-500-2013-008/CEC-500-2013008.pdf#51 pp. A-5 to A-18.

Results of Benefits Assessment Conducted for This Report

Estimated Quantifiable Benefits

Eighteen of the research projects had suffient data available to estimate quantifiable benefits. The results are summarized in Tables B-3.1 and B-3.2 for the areas of energy efficiency and natural gas research transportation.

Leveraging of Funds

The Natural Gas funding allocated to the ongoing and complete projects described in Appendix B totals $90.3 million. These projects leveraged a total of $52.3 million in match funding from federal and private partners.

Economic Stimulus Benefits

In selecting award recipients, the Energy Commission strives to maximize benefits to California ratepayers. In addition, consideration is given to ensure that ratepayer funds are invested back into California's economy through local universities, businesses, and other entities. Of the 108 total projects, the work of 97 occurred in California.

Proposed Future Practice

Energy Commission staff considers the method implemented for this report as a basis for future enhancements in providing accurate, useful, and nuanced benefits assessments. The staff provided substantial feedback regarding the data collection process, which will be incorporated into the design of future databases and questionnaires. These improvements will:

- Expand the collection and evaluation of project data in support of benefits such as health, safety, and reliability.
- Apply strict data validation rules, which prevent responses not suited to the nature of questions or project.
- Provide transparency in the calculations to be performed.
- Include baseline data that describe the recent past, present, or future state of California's energy markets and its general economy. This will also maximize consistency across benefits estimates.
- Consistently track and update data. As projects progress and reach completion, estimates are likely to be refined.

With regard to in-depth analysis, the past practices of the Energy Commission will remain essentially the same. In-depth analyses will continue to be published periodically, with a focus on projects of the greatest impact. The calculations, methodology, and assumptions will continue to be tailored specifically to each in-depth analysis. Where possible, in-depth analyses will rely upon baseline data stored within the aforementioned database to ensure consistency. The benefits estimates generated by in-depth analyses will also be stored in the database for ease of reference.

GLOSSARY

Acronym or Abbreviation	Definition
ARB	California Air Resources Board
CBE	California-based entity
CCHP	Combined cooling, heat and power systems
CHP	Combined heat and power
CO	Carbon monoxide
CO_2	Carbon dioxide
CPUC	California Public Utilities Commission
EISG	Energy Innovations Small Grant Program
EPA	Environmental Protection Agency
GGR	Gas Guard Regenerative
GHG	Greenhouse gas
GTI	Gas Technology Institute
GWh	Gigawatt hours
HPDI	High-pressure direct injection
IEPR	*Integrated Energy Policy Report*
kWh	Kilowatt hours
LBNL	Lawrence Berkeley National Laboratory
LCFS	Low Carbon Fuel Standard
LFG	Landfill gas
MMbtu	Million British Thermal Units
MW	Megawatt
NO_2	Nitrogen dioxide
NO_x	Nitric oxide
PG&E	Pacific Gas and Electric

PON	Program Opportunity Notice
R & D	Research and development
RFP	Request for Proposals
SCR	Selective catalytic reduction
THC	Total hydrocarbons
U.S. DOE	United States Department of Energy
ZNE	Zero net energy

APPENDIX A:
Natural Gas Research Projects Approved in FY 2012-13

Table A-1: New Natural Gas Funded Research Projects, Fiscal Year 2012-13 *

Agreement	Project	Project Title	Entity	Location	NG Funding	Match Funding
500-98-014, amendment 8		Energy Investment Small Grant Program (ESIG)	San Diego State University	San Diego, CA	$1,790,000	$0
500-12-003	1	Guidebook on Title 24 Benefits for Local Governments	UC Berkeley	Berkeley, CA	$200,000	$0
500-12-006	1	Top-Down Quantification of Methane Emissions from California's Natural Gas System	UC Davis	Davis, CA	$900,000	$0
500-12-008	1	Development of Natural Gas Vehicle Research Roadmap	National Renewable Energy Laboratory	Golden, CO	$313,000	$0
500-12-009	1	Impact of Natural Gas Comp-osition on the Performance and Emission of Heavy/Medium-Duty Natural Gas Vehicles - Phase 2	UC Riverside	Riverside, CA	$400,963	$120,000
500-12-010	1	Investigations of Potential Induced Seismicity Related to Geologic Carbon Dioxide Sequestration in California	Lawrence Berkeley National Laboratory	Berkeley, CA	$575,423	$0
500-12-012	1	Low NOx Natural Gas Engine Development for Heavy-Duty Vehicles	South Coast Air Quality District	Diamond Bar, CA	$2,000,000	$0
PIR-12-002	1	Green Waste to Renewable Natural Gas by PyroBioMethane	Anaergia Services	Carlsbad, CA	$395,121	$437,093
PIR-12-007	1	Renewable Natural Gas Production with Value-Added Fertilizer Co-Product	CleanWorld	Sarcamento, CA	$820,000	$690,830
PIR-12-009	1	Commercialization of ILI Technology which Accurately Detects, Locates, and Measures Pipeline Girth Weld Defects	Diakont Advanced Technologies, Inc	San Diego, CA	$1,000,000	$1,600,000
PIR-12-013	1	Real-time Active Pipeline Integrity Detection (RAPID)	Acellent Technologies	Sunnyvale, CA	$622,622	$0
PIR-12-014	1	Benefits of Dynamic Skip Fire for Improved Natural Gas Engine Performance	UC Berkeley	Berkeley, CA	$600,000	$125,600
PIR-12-017	1	Advanced 6.7 Liter Natural Gas Engine Development	Gas Technology	Des Planes, IL	$1,000,000	$2,164,735
PIR-12-020	1	Carbon Dioxide Based Co-Products from Renewable Natural Gas Fuel Production	UC Riverside	Riverside, CA	$359,847	$0
PIR-12-021	1	Interra Reciprocating Reactor to Produce Low-Cost Renewable Natural Gas	Interra Energy, Inc.	San Diego, CA	$818,147	$228,146
PIR-12-023	1	Demonstration of a Solar Thermal Heat Pump System	Chromasun, Inc	Huntington Beach, CA	$935,100	$404,192
PIR-12-024	1	ZNE Demonstration- Integration of Dynamic Daylighting and Passive Cooling/Heating for High Return on Investment	View, Inc.	Sunnyvale, CA	$500,000	$1,553,326
PIR-12-025	1	Demonstrating Scalable Very Energy Efficient Retrofits for Low Income, Multifamily Housing	Electric Power Research Institute	Lancaster, CA	$500,000	$1,142,800
PIR-12-026	1	Innovative Low-Energy Occupant-Responsive Controls for Heating, Ventilation and Air Conditioning Systems	California Institute for Energy and Environment	Berkeley, CA	$1,000,000	$192,500
PIR-12-027	1	Codes and Standards Quality Demonstration Program	UC Davis	Davis, CA	$525,000	$121,600
PIR-12-028	1	Advanced Envelope Systems for Factory Built Homes	The Levy Partnership	Sacramento, CA	$1,304,261	$299,781
PIR-12-029	1	Building Energy Efficient Cooling and Heating (BEECH)	Altex Technologies Corporation	Sunnyvale, CA	$1,582,817	$176,900
PIR-12-030	1	Improve Energy Efficiency of Hot Water Distribution Systems in Multifamily Buildings	Enovative Group, Inc.	Sacramento, CA	$1,061,800	$12,000
PIR-12-031	1	Small and Medium Building Efficiency Toolkit and Community Demonstration Program	Lawrence Berkeley National Laboratory	Berkeley, CA	$1,329,399	$254,790
PIR-12-032	1	Tools and Materials for Zero Net Energy California Buildings	UC Los Angeles	Los Angeles, CA	$700,000	$0
Totals:	25 Agreements		24 in California		$19,443,500	$9,524,293

APPENDIX B:
Technology Market Benefit Assessment

Table B: Natural Gas Benefits Assessments

Please see attachment for Appendix B, Tables B-1 through B-4.

Table B-1: Active Research Projects in the FY 12/13 Natural Gas Portfolio

	Number of Projects	NG Funding	Match Funding	Total
Energy Efficiency	40	$ 26.0	$ 13.0	$ 39.0
Renewable Energy & Advanced Generation	25	$ 22.8	$ 17.0	$ 39.8
Energy-Related Environmental Research	18	$ 16.4	$ 0.3	$ 16.7
Natural Gas Related Transportation	21	$ 22.5	$ 20.5	$ 43.0
Natural Gas Pipeline Integrity	4	$ 2.6	$ 1.6	$ 4.2
Total	108	$ 90.3	$ 52.3	$ 142.6

Funding reported in millions of dollars. Funding amounts listed refer to "not to exceed" allocated agreement amounts. Approved invoices for currently active projects may result in lower spending than shown above.
Note: Of the 108 projects, 97 are located in California.

Table B-2.1: Description of Energy Efficiency Projects

Agreement	Project	Project Title	Recipient	Project Location	NG Funding	Match Funding	Goal	Project Objectives
500-08-023	1	Energy and Water Recovery with Transport Membrane Condenser	Gas Technology Institute	Santa Ana, CA	$479,650	$486,842	To demonstrate an advanced Heat Recovery System (HRS) for recovering energy and water from low grade waste heat streams which are typically present in food processing, paper drying, and chemicals production. The development will be based on the nanoporous membrane-based Transport Membrane Condenser (TMC) technology developed by Gas Technology Institute (GTI). This project will design, build, test, and demonstrate a prototype TMC system at a suitable industrial site in California.	Substantiate an installed cost which will ensure marketability of the manufactured product Performance measures are to: Increase energy efficiency of the drying process by at least 10% (Higher heating value) Confirm the ability of the TMC system to meet an energy efficiency-increase target for the host site drying system Validate an installed cost projection for the end user low enough for a payback time of less than two years based on fuel savngs.
500-08-024	1	Advanced Residential Energy and Behavior Analysis Project	Portland State University	Portland, OR	$2,197,887	$0	To develop next-generation models, data sources, policy and technology analyses to provide an improved understanding of residential demand for natural gas. The results are intended to improve energy policies and energy efficiency programs, and to accelerate the reduction of California greenhouse gas emissions.	Perform a series of detailed micro-analyses to inform current policy efforts Determine the limits of current residential sector energy use and conservation models and data sources Construct and test next-generation models Collect data needed to support advanced modeling and analysis
500-08-026	1	Energy Efficiency Calculator Tools	Southern California Gas Company	San Diego, CA	$200,000	$219,441	To develop web-based software and desktop tools to aid California industries to identify, analyze and prioritize energy savings opportunities.	Provide a compilation of web-based software tools or calculators to be posted on the CEC website and be available for all California businesses
500-08-037	1	Waste Heat Recovery from Corrosive Industrial Exhaust Gases	Gas Technology Institute	Des Plaines, IL	$490,000	$470,000	To demonstrate a practical, robust, and affordable technology to recover useful waste heat from corrosive industrial exhaust gases. Since no practical technology exists to recover heat from these exhaust gas streams, this new approach offers a dramatic opportunity to improve energy efficiency for many industrial processes.	Provide a cost effective heat recovery technology which will make it possible to provide a 15% to 30% energy savings to sites using the technology. Gas Guard Recuperator (GGR) technology can be installed on furnaces in the aluminum, glass, and other industries that currently have no potential for waste heat recovery.

Table B-2.1: Description of Energy Efficiency Projects

Agreement	Project	Project Title	Recipient	Project Location	NG Funding	Match Funding	Goal	Project Objectives
500-08-042	3	Envelope Sealing with Adhesive Mist	Western Cooling Efficiency Center (UC Davis)	Davis, CA	$200,000	$0	To provide better tightness levels and automated documentation of tightness at a considerably lower cost than current manual envelope sealing methods. Provide quicker, less-expensive compliance with codes that impact energy use in buildings, and reduce infiltration load.	To further evaluate and develop the use of aerosol-based leakage sealing for building envelopes.
	4	Phase Change Materials for Hydronic Heating Systems			$100,000	$0	To increase the hydronic systems energy efficiency by replacing the water heat transfer medium with a water-PCM medium to increase the heat transfer capacity.	Investigate and quantify the energy savings associated with using a microencapsulated phase change material (PCM) to improve the efficiency and capacity of hydronic systems used for heating and cooling.
500-08-044	2	Personal Comfort Systems (PCS)	Center for the Built Environment (UC Berkeley)	Berkeley, CA	$150,000	$0	To develop, test and demonstrate personal comfort systems which can improve occupant comfort and reduce energy use in buildings.	Influence the manufacture of future PCSs through presentations to the building industry and specifications for clients and standards organizations
								Demonstrate the energy and comfort impacts of PCS devices in different types of buildings, both conventional and energy-efficient
								Demonstrate how PCSs should be integrated with existing building controls to harvest the energy-saving made possible by PCSs
	3	Space Conditioning in Near Zero-Net-Energy Buildings			$150,000	$0	To develop, test, demonstrate and publicize best practices for designing and controlling thermal comfort systems in near zero-net-energy buildings	Provide to the professional design community new and improved information, guidance, and tools for designing and operating near ZNE buildings using radiant heating and cooling systems.
500-08-051	1	Advanced Radiant HVAC Systems for California Homes	Gas Technology Institute	Sacramento, CA	$1,086,778	$240,432	To evaluate design options and establish the cost effectiveness of a low-cost, ceiling mounted, residential radiant cooling system and an accompanying hydronic heating system.	Increase the adoption of radiant HVAC systems in California housing
								Demonstrate the efficacy of a prototype radiant heating and cooling system when coupled with integrated installation techniques

Table B-2.1: Description of Energy Efficiency Projects

Agreement	Project	Project Title	Recipient	Project Location	NG Funding	Match Funding	Goal	Project Objectives
500-08-060	1	Residential Water Heating Program	Gas Technology Institute	Multiple Locations in CA	$1,984,761	$406,766	To analyze the functioning of residential water heating systems in the field and the greatest opportunities for energy savings. The project will provide critical information to improve water and energy efficiency standards, by identifying which of these opportunities can most readily be achieved given cost constraints, typical design practice, available technologies and cultural factors. The research will also provide significant outreach including nine best-practice training workshops in conjunction with California utilities for plumbers, homebuilders, code officials and others. Energy saving opportunities will be identified and quantified.	Advanced water heating system training for the plumbing trades and others working with product manufacturers to improve performance and/or reliability. Evaluations from laboratory heating and venting equipment Efficient water heating equipment and piping system designs and best practices guides Performance of water heater field monitoring and consumer behavior studies Integrating hot water generation and distribution and providing an analysis tool Improving water heater standard test method and rating and informing building and energy code with new developments
500-09-044	1	Advanced Foodservice Appliances for California Restaurants	Gas Technology Institute	San Ramon, CA	$1,985,502	$917,875	To significantly improve efficiency of commercial gas appliances through data collection and product design/development. This project will improve full-load and in-kitchen utilization efficiency of commercial gas appliances and water heaters through improving burners, heat exchangers, equipment design, and control systems.	Improve the efficiency of commercial oven top ranges by 15% Improve the efficiency of commercial conveyor ovens by 12% Improve the efficiency of commercial convection ovens by 14% Improve the efficiency of commercial woks by 20% Improve the efficiency of commercial under-fired broilers by 17% Improve the efficiency of commercial water heating systems by 15%
500-10-014	1	Central Valley Research Home Program	Bruce Wilcox	Stockton, CA	$532,091	$880,000	To develop life cycle cost effective residential retrofit packages that will reduce heating and cooling energy use by 50 percent or more in experimental homes. Improve HERs rating calculations for baseline existing homes and estimating the savings associated with retrofits.	Improve HERS software to produce better estimates of existing home pre and post retrofit energy use Produce a technology transfer plan Identify and characterize alternative conditioned air distribution systems Develop life cycle cost effective residential retrofit packages that will reduce heating and cooling energy use by 50 percent or more in experimental homes in Central Valley climate zones.

Table B-2.1: Description of Energy Efficiency Projects

Agreement	Project	Project Title	Recipient	Project Location	NG Funding	Match Funding	Goal	Project Objectives
500-10-015	1	Large Scale Residential Retrofit Program	Davis Energy Group, Inc.	Stockton, CA & Pleasanton, CA	$224,994	$1,000,000	To demonstrate that a coordinated program of projects designed to complete large numbers of integrated residential retrofits is cost effective and will generate significant GHG emission reductions. The LSRRP will develop retrofit designs based upon building science principles. It will include training, a quality control regimen, and competitive financing.	To estimate the impacts of the LSRRP, the problem should be split into two categories: houses that will actually receive retrofits through the efforts of the LSRRP; and houses that are likely to benefit by the after effects of a successful demonstration program. To estimate the benefits of the proposed project in California, a simulation program using Building Energy Optimation (BEopt), was used to determine savings for a typical home built in 1990s, of approximately 1,800 square feet in climate Zone 12, to exceed California Energy Commission's Title 24 Building Standards. Target natural gas savings of 57 therms per home.
								Three "packages" of energy efficiency measures were developed based on the BEopt analysis of the example house. The first package includes window film, attic insulation, weatherization, duct tightening, and lighting upgrades; the second adds an air conditioner retrofit; the third adds a Photo Voltaic (PV) system and other upgrades.
500-10-019	1	Unique Multifamily Code-Relevant Measures for the Title 24 Energy Standards Update	Benningfield Group	Sacramento, CA	$646,039	$608,800	To produce proposed 2016 energy code measures for multi-family buildings specific to ventilation, fenestration (window systems) and smart controls that give customers more control over energy use.	Investigate and better understand the codes and standards requirements and assumptions related to ventilation in multifamily buildings
								Explore cost-effective retrofit systems to improve fenestration systems in multifamily Buildings. Develop energy code proposals for multifamily fenestration standards.
								Apply, test, demonstrate, and assess available technologies and installation options for smart control technologies and displays that provide real time energy information for multifamily tenants.
								Develop code revision proposal(s) to address the discontinuity between the treatment of low-rise and high-rise multifamily residential buildings in Title 24, part 6.
								Explore cost-effective remediation and retrofit systems to improve multifamily ventilation systems and develop energy code proposals for multifamily ventilation standards.

Table B-2.1: Description of Energy Efficiency Projects

Agreement	Project	Project Title	Recipient	Project Location	NG Funding	Match Funding	Goal	Project Objectives
500-10-048	4	Improving Heating/Cooling Systems with Phase Change Materials	Western Cooling Efficiency Center (UC Davis)	Davis, CA	$275,024	$0	To study the feasibility of improving the effectiveness of water as a working fluid for heat transport by adding encapsulated phase change materials (PCM). Feasibility will be studied in the laboratory by selecting appropriate encapsulated PCM beads, measuring the performance of the heat exchange process using the PCM working fluid, and testing and specifying appropriate pumping systems for the PCM working fluid.	Determine the optimum encapsulated PCM to use in a central heating and/or cooling water distribution system. Current candidates include paraffin and salt hydrates. Considerations in selecting the encapsulated PCM include durability, specific gravity, and the heat of fusion.
								Disseminate the results of the research through the heating and air conditioning industry.
								Produce a prototype system for evaluation in a laboratory setting to measure system performance and quantify energy savings.
								Test existing pumping methods with encapsulated PCM beads, and, if required, develop a pumping system that will allow the PCM material to pass through without damage.
	5	Mini-Channel Technology to Improve Solar Water Heaters	UC Merced	Merced, CA	$333,202	$0	To design and manufacture a minichannel-based solar water heater and demonstrate its improved performance with respect to a standard round-tube flat-plate solar water heater.	Demonstrate improved efficiency of minichannel water heater performance compared to an actual standard round-tube flat-plate solar water heater.
								Perform tests and measure its performance for all four seasons of the year.
								Design and build a 1.8m^2 minichannel solar water heater.

Table B-2.1: Description of Energy Efficiency Projects

Agreement	Project	Project Title	Recipient	Project Location	NG Funding	Match Funding	Goal	Project Objectives
500-10-052	6	Simulation Models for Improved Water Heating Systems	Lawrence Berkeley National Laboratory	Berkeley, CA	$461,454	$0	To reduce natural gas and water used in residential domestic hot water applications by developing improved simulation models for building standards development.	Re-code software models using state-of-the-art tools and techniques Deconstruct existing hot water simulation models Make the models publicly available Correcting and augment models with lab work and new information, where needed
	7	Reducing Waste In Residential Hot Water Distribution Systems			$765,699	$0	To improve performance of residential hot water distribution systems in California through improved T24 standards for residential plumbing construction. The research will include a field study of water use in six California houses and developing estimates for the efficiency of the hot water systems. These data will enable the development of simulation tools. The results of this study will be presented at forums.	Measure the temperature and flow of water and energy into and out of residential HWDS Calculate the waste of water and energy attributable to the HWDS.
	16	Graphical User Interface for Energy Plus			$147,236	$0	To make EnergyPlus features more accessible to enhance the tool's value for its target audience and develop additional interface features in the areas of advanced heating and cooling systems, envelope systems, and advanced service hot water generation and distribution.	Increase adoption of advanced envelope, heating, cooling, and hot water distribution systems in California buildings through usability enhancements to Energy Plus.
	17	Energy IQ Action-Oriented Benchmarking			$147,236	$0	To provide upgrades to EnergyIQ Action-Oriented Benchmarking software to improve functionalirty and energy efficiency opportunities in commercial buildings.	Improve the energy efficiency of commercial buildings and use of benchmarking standards through improved functionality of the EnergyIQ “action-oriented” energy benchmarking tool.
	18	Improving Residential Programmable Thermostats			$38,747	$0	To define successful approaches to thermostat interface design so that thermostat designers can produce products that will actually be programmed and achieve the potential of these devices.	Reduce energy use by improving usability of programmable thermostats and other energy features on electronic devices by establishing standards and guidelines for usability.
	19	More Efficient Residential Heating/Cooling by Airflow Instrument Standards			$98,158	$0	To develop a standard test for qualifying airflow instruments for measuring air flow at return grills, to assure that qualified instruments will be accurate enough for meaningful results.	Improve the overall system performance of residential HVAC systems by improving measurements of air flow at return grilles.

Table B-2.1: Description of Energy Efficiency Projects

Agreement	Project	Project Title	Recipient	Project Location	NG Funding	Match Funding	Goal	Project Objectives
500-10-058	1	Grid-Saver Fast Energy Storage Demonstration	Trans-portation Power, Inc.	Poway, CA	$588,505	$520,004	To evaluate the feasibility of designing a lower cost fast energy storage system based on innovative design concepts and validate concepts via a prototype Demonstration phase.	Perform the analyses and trade studies required to optimize a system designed to meet the goals Complete a cost-benefit analysis to validate the benefits of specific design concepts Perform initial testing of the prototype system in a laboratory setting to validate the proof of concept and assess natural gas savings. Establish a foundation for successful commercialization of this energy saving technology through technology transfer activities and production planning
500-12-003	1	Guidebook on Title 24 Benefits for Local Governments	UC Berkeley	Berkeley, CA	$200,000	$0	To document the costs and benefits to local governments of mandatory and voluntary natural gas efficiency standards for residential and nonresidential buildings. Identify factors that affect the costs and benefits to local governments, and the factors that incentivize or impede achievement of benefits. To communicate research findings to local government agencies that implement Title 24, Part 6.	Greater achievement of the Standards' anticipated statewide energy and monetary savings through improved enforcement by local government agencies Improved understanding of economic benefits of building energy efficiency to key decision-making and enforcement entities Improved local government support for future Standards updates and other state and local building energy efficiency initiatives
PIR-08-023	1	Improving Efficiency of Spark-Ignited, St-oichiometrically operated Natural Gas Engines	Sturman Industries	Woodland Park, CO	$997,696	$230,401	To improve the brake thermal efficiency and eliminate engine knock of a spark-ignited stoichiometrically operated (SISt) natural gas engine, while maintaining ultra-low emissions levels in compliance with CARB standards. The project adapted a natural gas vehicle engine for use in stationary applications. The stationary application featured a hydraulic valve actuation system that reduces the fuel consumption of SISt engines, lowering fuel costs and CO2 emissions.	Design a flexible and common engine architecture that can maximize efficiency in both mobile and stationary applications. Demonstrate that the engine can comply with CARB emission limits while achieving a peak brake thermal efficiency greater than 40%, during steady-state dynamometer testing utilizing a 13-mode composite test procedure.

Table B-2.1: Description of Energy Efficiency Projects

Agreement	Project	Project Title	Recipient	Project Location	NG Funding	Match Funding	Goal	Project Objectives
PIR-08-043	1	Enabling Renewable Energy, Energy Storage, Demand Response and Energy Efficiency with a Community Based Master Controller-Optimizer	UC San Diego	San Diego, CA	$555,070	$1,057,445	To develop a fully integrated, future-proofed master controller that will optimally control multiple distributed electricity and natural gas systems in a microgrid. Automation will reduce barriers to entry for their adoption. Increased dissemination of microgrids will provide more platforms for the adoption of distributed natural gas generation. The master controller will optimize natural gas use efficiently.	Develop a semi-autonomous microgrid master controller for real-time optimization and management of multiple generation sources, loads, and natural gas utilization. Demonstrate the operation of the master controller on UCSD's microgrid and measure natural gas savings.
PIR-09-004	1	Integrated Waste Heat and Wastewater Recovery DOME for Food Processing Applications	Gas Technology Institute (GTI)	Oxnard, CA	$400,000	$125,000	To demonstrate the combination of wastewater recovery with waste heat utilization. Concept development and lab-scale evaluation will be performed in GTI's testing facilities with support and guidance of a leading CA-based food processor, Gills Onions. Successful development and demonstration of the technology for food processing applications will provide large energy and water savings to the industry.	Analyze laboratory scale DOME performance in general and relative to the Gills Onion application. Prepare a concept design for the laboratory scale evaluation / demonstration of the DOME system. Coordinate with Gills Onion on DOME performance characteristics (water production, quality, waste streams, etc.) so that technical and economical details can be evaluated. Fabricate and procure all necessary equipment for the laboratory scale DOME unit. Prepare a commercialization plan including locating a commercializing partner. Assemble and perform laboratory evaluation/demonstration of the DOME concept.
PIR-10-008	1	The Use of Novel Nanoscale Materials for Sludge Dewatering: A Field Demonstration	Kennedy/Jenks Consultants	Los Angeles, CA	$299,956	$174,989	To improve energy efficiency and reduce the carbon footprint of sludge dewatering/disposal during wastewater treatment. This will be achieved using innovative nanoscale additives during polymer-aided dewatering. A field demonstration study will be performed at Los Angeles County Sanitation District (LACSD) Joint Water Pollution Control Plant (JWPCP) at Carson, CA.	Demonstrate through lab and field studies improvement in energy efficiency during dewatering, reduction in sludge mass (i.e. increase in percent solids) requiring disposal, improvement in supernatant quality, reduction in polymer dose requirement Identify the nanoadditive composition (single or in combination) that is best suited for different sludges Develop preliminary cost estimates to show economic viability of the proposed technologies Develop and characterize nanoscale additives for different dewatering aid characteristics,

Table B-2.1: Description of Energy Efficiency Projects

Agreement	Project	Project Title	Recipient	Project Location	NG Funding	Match Funding	Goal	Project Objectives
PIR-10-017	1	Supercritical CO2 Cleaning and Sterilization of Commercial / Industrial Textile	CO2Nexus Inc.	Los Angeles, CA	$396,000	$1,358,988	To validate and document the technical and commercial feasibility of a dense phase CO2 textile cleaning and disinfection machine and a process for laundering fabrics. These include items such as gowns, scrubs, lab coats, and other miscellaneous textiles that are currently utilized in biotech, medical, pharmaceutical, semiconductor, and other industries. The cleaning of such textiles typically requires significant amounts of water and are disinfected with chemicals that produce a costly secondary waste stream.	Reduce green house gas (GHG) emissions, reduce effluent water from commercial and industrial laundry, and provide a cost saving technology to the public. Eventual successful roll-out of this technology in large scale. Increase consumer awareness of CO2 textile cleaning. Determine the real world operation and cost comparisons between water-based and CO2-based textile cleaning in an industrial setting. Measure and validate the technical and economical performance of this machine, including cleaning performance, cycle time, workflow efficiency, energy and water consumption, and reliability. Design and build a commercial-scale dense phase CO2 textile cleaning sterilization machine.
PIR-10-018	1	Advanced Software for Demand and Energy Reduction in California Pipelines	mc2 Consulting, Inc.	Atlanta, GA	$399,565	$124,283	To evaluate combined use of optimization software and a drag-reducing agent to provide a tool for estimation of energy savings versus cost of operations, and to use a Project Advisory Committee (PAC) mechanism to help enhance evaluation and dissemination of results.	To model energy savings possible with the use of advanced software over a range of drag-reducing agent use, and then measure the actual energy savings obtained through live use of the software and DRA on oil and gas pipelines. Create a software package that will allow other pipeline companies to estimate their possible energy savings. As more data is made available through wider use of the software and DRA, data points can be added to the nomograph model, enhancing accuracy and extrapolation range.
PIR-11-006	1	Novel Hydrodynamic Separation Technology for Wastewater Treatment	Palo Alto Research Center, Inc.	Sunnyvale, CA	$973,089	$380,817	To demonstrate the Hydrodynamic Separation Technology to significantly reduce the energy footprint of a waste water treatment plant.	Demonstrate that the Hydrodynamic Separation Technology can continuously perform in a real wastewater plant for at least two weeks without significant degradation in the Hydrodynamic Separation Technology separators. Enable a net energy savings through both reduced energy usage in wastewater treatment and increased biogas production in digesters. Achieve at least 70% removal of solids on a weekly average basis.

Table B-2.1: Description of Energy Efficiency Projects

Agreement	Project	Project Title	Recipient	Project Location	NG Funding	Match Funding	Goal	Project Objectives
PIR-12-024	1	ZNE Demonstration-Integration of Dynamic Daylighting and Passive Cooling/Heating for High Return on Investment	View, Inc.	Sunnyvale, CA	$500,000	$1,553,326	To validate an innovative Zero Net Energy (ZNE) renovation design integrating multiple advanced emerging technologies that enables immediate payback, net-positive cash-flow, and higher ROI than conventional construction. This project will demonstrate how the unique tinting and solar gain characteristics of dynamic glass amplify the effect of the other emerging efficiency measures, and will achieve the compelling ROI in a design that can easily be replicated in most California commercial and residential buildings.	Demonstrate a commercial ZNE renovation that reduces cooling energy by 3x at a capital cost for heating, ventilation, and air conditioning (HVAC) 5x lower than required by Title 24 Has an incremental ROI greater than market rate on comparable non-sustainable construction (7.5%) Generates sufficient incremental net-operating income to provide a positive cash-flow after servicing debt equal to the total incremental renovation costs over Title 24 Reduces heating energy by 7x at an HVAC capital cost 5x lower than required for Title 24
PIR-12-025	1	Demonstrating Scalable Very Energy Efficient Retrofits for Low Income, Multifamily Housing	Electric Power Research Institute	Lancaster, CA	$500,000	$1,142,800	To provide and demonstrate to the low-income multifamily housing industry easily replicable technical and financial tools to support and encourage widespread Very Efficient Retrofits (VER) and to develop cost effective and replicable VER packages with energy-savings of at least 40% improvement over baseline (at least meeting 2008 Title 24 energy performance standards). The package may potentially include natural gas-saving retrofits, such as buidling envelope and HVAC measures.	Research measures, technologies, and building practices to make the VER packages as close as possible to ZNE capable and still practical, cost-effective and replicable. Demonstrate, measure and evaluate the VER packages in the targeted community and define the financing requirements of, and barriers to VERs in the low-income multifamily housing industry. This information will provide insightful recommendations to the financing industry for specific financing vehicles needed for widespread replication of the VER packages. Develop practical, replicable VER packages for low income multifamily housing. This objective will be met by employing the most recent technical advances to improve existing buildings to, at a minimum current (2008) energy efficiency Title 24 standards.

Table B-2.1: Description of Energy Efficiency Projects

Agreement	Project	Project Title	Recipient	Project Location	NG Funding	Match Funding	Goal	Project Objectives
PIR-12-026	1	Innovative Low-Energy Occupant-Responsive Controls for Heating, Ventilation and Air Conditioning Systems	California Institute for Energy and Environment (UC Berkeley)	Berkeley, CA	$1,000,000	$192,500	To develop, evaluate, integrate, demonstrate, and plan for the scaled deployment of three innovative strategies that will dramatically improve both energy efficiency and occupant comfort in buildings. These include: low-energy personal comfort systems (PCSs) that provide direct local heating and cooling to building occupants and test methods for assessing the efficiency of PCSs; innovative control improvements to variable air volume (VAV) reheat systems; and open-source software for implementing actuation control logic across a full range of legacy or new direct digital control (DDC) systems.	Demonstrate integrated applications of the innovations with occupant-based HVAC controls. Implement the results in codes and standards such as Titles 20 and 24 of the California Code of Regulations, and Standards 55 and 90.1 of the American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE) Standards. Develop and demonstrate innovative improvements to VAV control systems. Create a Demonstration, Deployment, and Commercialization Plan for the innovative strategies, with occupant-based HVAC controls. Demonstrate and bring to the market new low-energy, localized Personal Comfort Systems (PCSs), and develop methods for certifying their efficiency. Use open-source information technology software for implementing actuation control logic across a full range of DDC systems. Perform technology transfer activities to encourage adoption of the standards in common practice.
PIR-12-027	1	Codes and Standards Quality Demonstration Program	UC Davis	Davis, CA	$525,000	$121,600	To develop a detailed demonstration and assessment program for Energy Commission-sponsored and other related building energy efficiency technologies. The CASE-Quality Demonstration Program (CASE-QDP) will provide: a complete, robust data set on key energy-efficient technologies; a data set that can inform and affect California CASE activities. Natural gas-saving technologies to be evaluated include HVAC systems.	Verify and document post-assessment performance Demonstrate the viability and success of the program through multiple assessment Deliver energy, market and economic analyses on all technologies to the Energy Commission and other Codes and Standards stakeholders for use in future iterations of CASE activities
PIR-12-028	1	Advanced Envelope Systems for Factory Built Homes	The Levy Partnership, Inc.	Riverside, CA	$1,304,261	$299,781	To develop new and innovative methods for building roof and wall systems that dramatically reduce energy use in factory built homes and take steps to transition the market in California to the new methods.	Have an annualized energy cost markedly lower than the current construction methods. Develop wall and roof designs that use continuous exterior insulation such as structural composite panels

Table B-2.1: Description of Energy Efficiency Projects

Agreement	Project	Project Title	Recipient	Project Location	NG Funding	Match Funding	Goal	Project Objectives
PIR-12-029	1	Building Energy Efficient Cooling and Heating (BEECH)	Altex Technologies Corporation	Sunnyvale, CA	$1,582,817	$176,900	To develop and demonstrate a waste heat and solar heat driven cooling/heating system, called the Building Energy Efficient Cooling and Heating (BEECH) System, for commercial buildings that will have a payback of under two years using waste heat and five years using waste and solar heat. The project will reduce building electricity and natural gas use, utility costs, ozone precursor pollutants (e.g., NOx and hydrocarbons) and greenhouse (GHG) gas emissions.	Perform technology transfer to promote customer interest in the BEECH system. Analyze waste heat- and solar-heat driven BEECH systems for commercial building applications of high interest for energy efficient enhancements. Design and fabricate 15 tons cooling and 360,000 Btu/hr (3.6 therms/hr) heating BEECH system to demonstrate its energy efficiency in relevant environments. Install in available commercial boiler and demonstrate the BEECH system to show at least 10% thermal efficiency improvement, 7.5% natural gas reduction, 1010 lbs/day greenhouse gas emissions and resultant ozone precursor pollutant reductions, and avoidance of 400 kWh in electrically-driven cooling costs. Perform production readiness evaluations to ready BEECH for commercialization. Using test results and initial full-scale design, evaluate waste heat and solar heat BEECH system performance and costs versus conventional mechanical vapor compression (MVC) cooling and hot water heating systems. Define the commercial potential of the BEECH system, with and without solar heat, considering markets, competition and payback.
PIR-12-030	1	Improve Energy Efficiency of Hot Water Distribution Systems in Multifamily Buildings	Enovative Group, Inc.	Venice, CA and 100 Site throughout California	$1,061,800	$12,000	To quantify energy and water impacts of crossover and unbalanced recirculation loops in domestic hot water systems. Provide best practices for identifying these issues. Access and survey a large sample set of buildings to measure the scale of the problem and evaluate a smaller sample in-depth with identified problems. Develop procedures for measuring the water and energy impact of balancing and repairing fixture crossover. Apply these procedures to the smaller sample of buildings. Compile results of the analysis and provide to key codes and standards stakeholders in California for creation of future efficiency programs.	Define the magnitude of the problem Create recommendations or new standards Develop techniques to properly diagnose crossover and balancing issues Develop a method for measuring energy performance Determine frequency and occurrence of unbalanced or crossover in multifamily systems Evaluate existing designs

Table B-2.1: Description of Energy Efficiency Projects

Agreement	Project	Project Title	Recipient	Project Location	NG Funding	Match Funding	Goal	Project Objectives
PIR-12-031	1	Small and Medium Building Efficiency Toolkit and Community Demonstration Program	Lawrence Berkeley National Laboratory	Berkeley, CA	$1,329,399	$254,790	To develop a Small-and-Medium-sized Building (SMB) Toolkit to enable and accelerate SMB retrofits. Lower energy use in the SMB sector by 4.5% in 2030, with further savings in future years, while improving indoor environmental quality.	Prototype a freely-available web-based CBES retrofit analysis tool, using the developed APIs to evaluate both individual and collective retrofit measures. Partner with California businesses, local governments, and investor-owned utilities (IOUs) to develop, test, and demonstrate the SMB Toolkit to validate a robust, practical, and effective SMB retrofit assessment method. Develop streamlined data collection and performance measurement systems that maximize existing data and approaches used in this sector. Demonstrate new advanced systems, methods, and tools with local cities and deployment partners, directly supporting AB 758 energy programs. Definition of the functional requirements for conducting SMB retrofit assessments. Development of an indoor environmental quality (IEQ) information and a ventilation measurement system for rooftop heating, ventilation, and air-conditioning (HVAC), to ensure that ventilation rates are adequate but not excessive.
PIR-12-032	1	Tools and Materials for Zero Net Energy California Buildings	UC Los Angeles	Los Angeles, CA	$700,000	$0	To improve energy efficiency in California's residential and commercial building stock. This project will develop a more effective type of high-mass building material; and a set of new software design tools to help building owners lower energy use.	Demonstrate a new type of building material that increases the effectiveness of thermal mass. Equip ordinary Californians with tools to encourage them to invest in ZNE buildings. Help Californians lower building energy use and peak demand in both new and existing residential and commercial buildings by making a commercial product available that has superior thermal and energy characteristics compared to current best practice.
Totals:		32 agreements	40 projects	29 projects in CA	$26,007,616	$12,955,780		

Table B-2.2: Description of Renewable Energy and Advanced Generation Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
500-08-006	1	Funding for UC Energy Institute to operate the Center for the Study of Energy Markets	California Institute for Energy and Environment (UC Berkeley)	Berkeley, CA	$500,000	$914,760	To conduct energy market research in five general areas: (1) reliability/adequacy of supply, (2) retail policies/demand response, (3) market design, (4) interactions of environmental regulation and energy markets. CSEM also sponsors research and policy conferences, and other elements of a tech transfer function, to communicate its research findings and opinions to policymakers.	Perform market research to inform policymakers to meet the requirements of Public Resources Code 25300(c) "The Legislature further finds and declares that the state government requires at all times a complete and thorough understanding of the operation of energy markets... to enable it to respond to possible shortages, price shocks, oversupplies, or other disruptions."
500-10-048	2	Advanced Combined Cooling Heat and Power for Building Efficiency	UC Irvine	Irvine, CA	$385,000	$0	To develop engineering tools for designing and operating combined cooling, heat and power (CCHP) systems by analyzing, optimizing and documenting performance of an existing CCHP system using natural gas-power fuel cells, liquid cooled photovoltaic cells, absorption cooling, heating, and thermal energy storage at the University of California Irvine (UCI).	Demonstrate the technical feasibility and economic viability of novel integrated fuel cell, absorption chiller, and solar CCHP systems. Analyze the thermodynamics and dynamics of the chiller, fuel cell and solar power data. Acquire dynamic data from a commercial absorption chiller, high temperature fuel cell, and solar power installations existing on the UCI campus, sufficient to characterize hourly behavior of each system with diurnal fluctuations in each season. Acquire corresponding data to characterize dynamics of electrical, heat and cooling demand of an existing representative campus building. Develop tools for conceptualizing, analyzing and designing integrated absorption chiller, high temperature fuel cell, and solar power systems.

Table B-2.2: Description of Renewable Energy and Advanced Generation Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
500-10-048	11	Enabling Renewable Fuels Through Flexible Burners	UC Irvine Combustion Laboratory	Irvine, CA	$357,500	$0	To develop and demonstrate the overall feasibility of a fuel flexible burner system that will respond to operating impacts associated with changes in fuel composition and to adjust its performance accordingly. Flexible fuels may include such fuels as unprocessed natural gas, coal bed methane, landfill and digester gas, syngas, and hydrogen.	Establish bench scale burner facilities platforms with which to evaluate fuel flexible burner concepts required to monitor and compensate for fuel composition variation. Burners will be developed and tested that can vary operational characteristics to facilitate control, including multiple fuel circuits or ability to vary flow splits.
								Map the performance of the bench scale burner and sensor(s) to controlled variation in fuel composition for use in the development of control algorithms. Analyze and correlate results.
								Prepare a database of relevant and measurable renewable and fossil fuel characteristics, and correlate the results with combustion behavior.
								Establish a means to complete closed loop control of the burner using the information from the sensors gathered.
								Establish a robust sensing methodology for either fuel composition or reaction characteristics that is sensitive to the impact of fuel composition.
								Analyze the results obtained using fuel interchange parameters being developed under an ongoing program and use the burner platform to validate/confirm the parameters developed.
	12	Gasification of Almond Shell Biomass for Natural Gas Replacement	UC San Diego	San Diego, CA	$463,852	$0	To provide engineering research and analysis of the production and use of clean fuel gas from gasification of almond shell byproduct, to facilitate development of distributed 1-5 MW combined heat and power plants to eliminate natural gas utilization by the California Almond Industry.	Reduce power production exhaust emission levels to meet or exceed CARB requirements for NOx (0.07 lbs/MW-hr) and CO (0.10 lbs/MW-hr)
								Achieve optimized gasification of almond shells at 80% efficiency in production of heat and power
								Achieve advanced gas cleaning to provide high quality producer gas with tar levels less than 0.1 gm/cubic Nm

Table B-2.2: Description of Renewable Energy and Advanced Generation Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
500-10-052	8	Encouraging Combined Heat and Power in California Buildings	Lawrence Berkeley National Laboratory	Berkeley, CA	$196,363	$0	To stimulate economic and environmentally sound natural gas-fired combined heat and power (CHP) and combined cooling, heating, and electric power (CCHP) adoption in California's medium-sized commercial building sector.	Place emphasis on the California restaurant sector since it is a major consumer of natural gas. Collect and forecast data on equipment performance (including emissions), tariffs, and other relevant parameters for 2020 and 2030, and the test buildings selected. Develop multiple scenarios that reflect grid de-carbonization, changes in equipment performance, and regulatory environment. Conduct Distributed Energy Resources Customer Adoption Model (DER-CAM) simulations for the chosen buildings for all the scenarios. Regional estimates of emissions, notably for Nitrogen Oxides (NOx), were derived. Consider zero net energy buildings and their impact on combined heat and power (CHP) and combined cooling, heating, and power (CCHP). Also consider feed-in tariffs.
500-10-064	1	Evaluation and Optimization of Concentrated Solar Power Coupled with Thermal Energy Storage	KEMA, Inc.	Oakland, CA	$447,642	$173,989	To define the benefits, costs, and impacts of increasing penetration of coupled concentrated solar power (CSP)-thermal energy storage (TES) to the California electricity grid, along with the system configurations and control strategies needed to optimize economic and engineering performance.	Define the reduction of area control error caused by the intermittency of concentrating solar generation from adding optimal storage configurations. Determine the most cost-effective CSP-TES configurations among existing technologies. Determine the market effectiveness of adding substantial coupled CSP-TES capacity to the California grid.

Table B-2.2: Description of Renewable Energy and Advanced Generation Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
PIR-08-041	1	Energy, Economic and Environmental Performance of Dairy Bio-power and Bio-methane Systems	Summers Consulting, LLC	Atwater, CA	$999,925	$0	To quantify, through a combination of field and laboratory studies, the technical, economic and environmental performance of California dairy biogas systems including manure and effluent handling, anaerobic digestion, and biogas-to-electricity and biogas-to-fuel generation processes. This goal is to be achieved by monitoring, sampling, and analyzing material flows, monitoring energy consumption and generation, and completing detailed element, mass, energy, and economic balances on six operating dairy digester systems.	Monitor six dairy operations in California with biogas systems that include a mix of digester technologies and end-uses for the biogas. Anlyze all relevant mass, volume, and energy flows for the integrated dairy power system including manure and effluent handling, anaerobic digestion, and biogas-to-electricity and biogas-to-fuel generation. Analyze the fate of solid, liquid, and gas phases of carbon, nitrogen, phosphorus, potassium, sodium, and sulfur, and their effects on energy, air, water, and land. Install continuous automatic data acquisition (15-minute interval) to record system power, flow, temperatures, pressures, and ambient conditions necessary to calculate a full mass and energy balance. Validate of engineering models of digester performance with reference to the observed data. Analyze cost/benefit information to evaluate system economic performance.
PIR-09-008	1	Solar Assisted Gas Hot Water Heating for Food Processing Industry	Gas Technology Institute (GTI)	San Miguel, CA	$381,402	$123,444	To reduce system costs while significantly increasing the installed efficiency of commercial water heating systems throughout California.	Demonstrate an efficient solar-assisted hot water distribution system that overcomes short and long term power interruptions. Reduce the required size and cost of commercial solar-assisted gas water heating systems through the use of advanced components, solar thermal hybrid integration, advanced operational strategies and installation methods. Disseminate information on commercial solar-assisted gas hot water systems in small winery applications and provide outreach materials through the Santa Barbara Country Vintners' Association, plumbers, and utilities for their use in energy efficiency programs. Prove the benefits and facilitate the market transformation of commercial solar-assisted gas water heating systems in small winery applications through demonstration. Develop a commercial solar-assisted gas hot water heating system with the potential for energy cost savings of 40% and a corresponding reduction in greenhouse gases in small commercial agribusinesses.

Table B-2.2: Description of Renewable Energy and Advanced Generation Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
PIR-09-018	1	Development and Demonstration of a Novel High-Temperature Fuel Cell Absorption Chiller CCHP System	National Fuel Cell Research Center (UC Irvine)	Irvine, CA	$450,000	$2,140,000	To proactively accelerate the deployment of high temperature fuel cell (HTFC) chiller technology into California's Combined Cooling, Heat, and Power (CCHP) market. The specific site selected for installation of the integrated system is a two-story, 63,300 square foot building known as "FlexTech" on the UC Irvine campus. The fuel cell will have a nominal electrical output capacity of 300 kW while the absorption chiller will provide a thermal output of 40 tons of refrigeration.	Optimize design of a CCHP system that recovers high quality heat from a high-temperature fuel cell through absorption chilling
								Establish power purchase agreement (PPA) with a utility to sell surplus electricity to the grid to increase economic value of the system
								Manufacture, install, and commission the system at the project site
								Collect engineering data to evaluate the technical performance of the system
								Evaluate the economics and market competitiveness of the system
								Engage with stakeholders to transfer the technology to the wider market
								Establish the readiness of the technology to enter commercial production
PIR-10-011	1	CASCADE Clean Energy System for Water and Wastewater	Cascade Clean Energy, Inc.	Dublin, CA	$204,981	$379,224	To build a prototype of the CASCADE Clean Energy System that is integrated with the existing wastewater treatment process at the Dublin San Ramon Service District to improve the system's waste to energy conversion.	Reduce the hydraulic retention time of the pilot wastewater treatment system compared to the current system
								Reduce the Biological Oxygen Demand (BOD) of the treated wastewater stream
								Improve methane production from wastewater and sludge by 30% or more
PIR-10-053	1	CHP Operation Using Emission Control Technology	Fiscalini Farms Management, LLC	Modesto, CA	$1,500,000	$375,000	To develop a Best Available Control Technology (BACT) to meet regulatory emission standards for combined heat and power systems operating at Califronia dairies. The project will collect system performance data to advance the market penetration of grid-connected CHP systems in California, helping owners to reduce energy costs and the state to achieve the RPS goal and GHG emission targets.	Establish baseline data by monitoring the performance of an existing biogas-fueled CHP system installed at Fiscalini Farms located in Modesto, California.
								Market the technologies developed in this project to California dairies, food processors, landfills, and wastewater treatment facilities to encourage renewable CHP in California.
								Design, install, and monitor pre-combustion chambers to determine the economic viability and technical feasibility of replacing the
								Determine operating reliability and economic viability of the SCR in a dairy biogas setting and develop information to determine the most economically viable and technically achievable NOx and other emission standards through system modification.
								Design, install, and monitor algae reactor technology to determine its effectiveness, economic viability, and technical feasibility of replacing the existing SCR and reducing additional air emission pollutants and GHG reduction.

Table B-2.2: Description of Renewable Energy and Advanced Generation Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
PIR-11-008	1	Demonstration of Advanced Biomas Combined Heat and Power Systems in the Agricultural Processing Sector	West Biofuels, LLC	Woodland, CA	$2,000,000	$1,450,829	To demonstrate a robust, efficient, and environmentally sound biomass-fired combined heat and power (BCHP) system that can be commercially deployed and reduce natural gas used in the agricultural processing sector in California.	Demonstrate emission controls for BCHP technologies that can meet CARB and regional air district standards.
								Demonstrate an ash byproduct suitable for recycling as fertilizer back to agriculture.
								Develop a techno/economic model for commercialization of BCHP to include a carbon and material life cycle analysis.
								Qualify the use of almond biomass feedstock for BCHP operations.
PIR-11-014	1	Data Center Demonstration with Combined Heat and Power Technology	ICF International	Monterey Park, CA	$974,179	$504,189	A combined heat and power (CHP) system consisting of three Capstone microturbines and one Thermax absorption chiller will be demonstrated at a data center operated by Southern California Gas Company.	Document that system reliability, availability, and power quality meet
								Confirm that the system will meet strict California emissions requirements
								Verify efficiency and greenhouse gas reduction levels sufficient to make the technology eligible for utility energy efficiency rebate programs in California
								Develop alternative energy sources for data centers
								Act as a real-world operating system to demonstrate the above capabilities to prospective data center customers
								Match thermal and electric outputs to an operating data center's load profile
PIR-11-016	1	Novel Flex Fuel Oxidation for Distributed Generation	ZERE Energy and Biofuels, Inc.	Mcclellan, CA	$998,346	$437,500	To design, build, demonstrate, and test a fuel flexible biogas CHP system employing ZERE's Air Independent Internal Oxidation (AIIO) process at the laboratory and prototype scales. The prototype will demonstrate production of electric power and heat in a system fueled by untreated biogases (e.g. dairy digester, wastewater treatment), natural gas, and mixtures thereof, and outperforming California Air Resources Board (CARB) 2007 emissions standards.	Demonstrate ZERE CHP system sustainability through full system life cycle analysis.
								Demonstrate electrical and CHP efficiency that when scaled to commercial size will be competitive with existing distributed CHP systems when evaluated at BACT or CARB 2007 emissions standards, whichever is more stringent.
								Demonstrate AIIO-based CHP can meet and exceed CARB 2007 emissions standards while operating with untreated biogas fuels, natural gas and mixtures thereof.
								Develop near-term and long-term commercialization pathways for ZERE fuel-flexible CHP systems.
								Demonstrate the ability of AIIO-based CHP systems to operate with untreated biogas.
								Quantify and rank the technical and economic performance of AIIO systems utilizing multiple flex-fuel configurations based on process models.

Table B-2.2: Description of Renewable Energy and Advanced Generation Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
PIR-11-023	1	Combined Heat and Power with Thermal Storage for Modern Greenhouses	Southern California Gas Company	Camarillo, CA	$1,502,699	$3,901,080	To assess, design and demonstrate the economical operation of CHP in a state-of-the-art greenhouse.	Assess economic performance on a forward basis, taking into account future capital cost improvements, shortening the time to a grid interconnection agreement and a PPA with SCE.
								To quantitatively measure the technical performance of an optimal CHP integrated greenhouse that includes maximum heat recovery and low heat loss thermal storage.
PIR-11-026	1	Municipal Digester Repowering Demonstration Project	UTS Bioenergy LLC	Hesperia, CA	$1,933,551	$607,722	To demonstrate retrofit technology which will allow wastewater plants to maximize biogas production and be energy self-sufficient.	The objective of this project is to determine and show the additional biogas that can be generated within the existing anaerobic digestion infrastructure and the retrofit and stable operation of high solids digester operations.
								To show that high strength waste can be co-digested with Muncipal sludge upto a 50% fraction resulting in enough biogas production that could generate enough electricity for the plant to be self-sufficient.
PIR-11-027	1	Tri-generation energy system technology (TRIEST)	Altex Technologies Corporation	Sunnyvale, CA	$731,770	$185,000	To engineer, build and demonstrate an innovative heat driven cooling system that will meet challenging CCHP and boiler air emissions standards, minimizing cost and optimizing operability by the synergistic coupling of a proven simple cycle microturbine-generator (SCMTG) and ultralow NOx burner and the integration of a low cost steam driven cooling system. This innovation will directly address the slow adoption of small CCHP systems by creating a low emissions and cost effective compact power, cooling and heating system for retrofit to the large population of firetube boilers in California.	Demonstrate steam driven cooling system has a COP of at least 0.6
								Show overall CCHP efficiencies of 82% when operating the SCMTG at full load
								Show that emissions and performance gains achieved in the BBEST platform are maintained in the TRIEST CCHP configuration. These include: Attaining low firetube boiler emissions levels in compliance with emissions regulations in all California regions; allowing boiler operation at low excess air, to minimize heat losses in the stack and reduce fuel costs; and providing payback of 1.5-2.0 years for most 100kWe installations.
								Perform subscale demonstration of steam ejector cooling technology
								Design an innovative, low-cost, steam driven cooling system based on the steam jet concept for expanding the capability of an existing CHP platform to include cooling capability

Table B-2.2: Description of Renewable Energy and Advanced Generation Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
PIR-11-028	1	Fuel-flexible, hybrid CHP at San Bernardino Municipal Water Department	Gas Technology Institute	San Bernardino, CA	$1,767,185	$870,388	To develop and demonstrate a hybrid partial oxidation gas turbine (POGT)-internal combustion engine (ICE), including organic Rankine cycle (ORC) for waste heat to electrical power generation, as a fuel-flexible hybrid generation CHP system to improve the performance and advance market penetration of distributed generation CHP systems in California.	Demonstrate that emissions from POGT-ICE hybrid generation system are at or below levels required by CARB 2007 limits for DG for biogas and biogas/natural gas blends. Demonstrate increased power production from renewable biogas/natural gas blend versus baseline. Demonstrate increased fuel to electricity efficiency Demonstrate CHP Thermal efficiency is increased. Develop and demonstrate a fuel-flexible hybrid generation CHP system at the San Bernardino Water Reclamation Plant
PIR-11-029	1	Demonstration of Waste Heat Recovery for Power Generation	Gas Technology Institute	South Gate, CA	$1,733,000	$850,000	To develop and demonstrate an effective waste heat recovery system for no-stack process heaters above 800 degrees F.	Prove the benefits and facilitate the transformation of the waste heat recovery market through demonstration. Prove the feasibility and safety of a commercial waste heat-to-electricity technology with the potential for effectively recovering waste heat in industrial furnace exhaust gases above 800 degrees F and converting it to electricity. Achieve a payback of less than 4.5 years for the demonstration system and projected paybacks of below 3 years for commercial systems. Prove the possibility of installing the system as a retrofit without downtime or any adverse impacts on furnace performance.
PIR-11-030	1	Demonstrate Integrated Renewable Energy Technologies for Biorefineries	Biodiesel Industries of Ventura, LLC	Five Points, CA	$1,829,544	$2,012,670	To integrate several emerging technologies to produce reliable on-demand primary renewable power for a biodiesel production facility. These technologies include: (1) combined solar power and heat, (2) modular gasification to convert oil seed extraction solids (inedible) into heat and power, and (3) anaerobic digestion to convert liquid by-products from biodiesel production (raw glycerin and wash water) to produce heat and power.	Document a pathway for producing biodiesel that increases use of renewables and waste products and also reduces energy cost, based upon data gathered from the demonstration and validation of the integrated technologies Quantify the displacement of natural gas and grid electricity for this system and the potential for similarly situated industries in California Provide an economic, and environmental assessment including compliance with CEQA and NEPA and local air district requirements Demonstrate and validate the ability of the integrated and interconnected technologies to meet the combined heat and power needs of a biodiesel production facility

Table B-2.2: Description of Renewable Energy and Advanced Generation Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
PIR-11-032	1	Algae-based Treatment of Dairy Wastewater & Generation of Renewable Energy	Quantitative BioSciences, Inc	Lakeside, CA	$1,500,000	$860,000	To develop and demonstration “turn-key” algae waste-water facility to increase biogas production and offset natural gas use. The simple and affordable algae waste-treatment facility should be able to replace the existing lagoon approach to waste treatment on farms. The implementation of these advanced pond system will be economical and profitable for the agricultural industry, as farms will be able to support higher value crops, offset energy expenses, and use or sell the resulting nutrient-rich algae biomass.	To develop an algae wastewater treatment system that improves the quality of water beyond the traditional approach, reduces greenhouse gas emissions, and produces energy.
PIR-12-023	1	Demonstration of a Solar Thermal Heat Pump System	Chromasun, Inc	Huntington Beach, CA	$935,100	$404,192	To demonstrate for the wider hospitality market a commercial-scale Solar Thermal Heat Pump project at a resort hotel.	Save measureable amounts of electricity from chiller load reduction Achieve better than 50% improvement in natural gas efficiency Establish 2 years of performance data that correlate closely with system integrated modeling Clarify factors which define site feasibility and project qualification Widely educate the hospitality market in California about the Solar Thermal Heat Pump Prepare for commercialization to meet market demand Provide a scalable technology suitable for not only hospitality, but other high-use domestic hot water industries, including, but not limited to hospitals, college dormitories, correctional institutions, multi-family residential, and food processing.

Table B-2.2: Description of Renewable Energy and Advanced Generation Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
PNG-07-004	1	Biogas-Powered Microturbine with Ultra-low Emissions for CHP Applications	Lawrence Berkeley National Laboratory	Oakland, CA	$500,000	$300,000	To develop a microturbine combustor system that can be turned down 50% while maintaining ultra-low emissions to satisfy the 2007 CARB requirements. The fuel handling system in turbines designed for natural gas operation may not be capable of maintaining system efficiency and reliability while operating on biogas and other low heat content fuels. Therefore, the combustor assembly must be designed for optimum performance with such fuels.	Operate a microturbine on biogas and meet CARB emissions standards without expensive post-combustion exhaust gas cleanup. Achieve microturbine operation on biogas with a normal maintenance cycle and avoid frequent maintenance associated with catalytic combustors. Demonstrate the ability for microturbines to transition to the CARB 2008 and 2013 emissions standards for waste gas with small incremental cost (<20%). Achieve a net system efficiency of more than 65% from the biogas-powered microturbine CHP package system. Project will develop and demonstrate a recuperated microturbine-based CHP system capable of operating on biogas, while achieving low emissions to meet the 2007 CARB requirements for fossil fuels. Develop a low swirl, ultra-low emission combustor for the microturbine that can operate over a range of heat contents that is suitable for many biogas sources, including landfills, wastewater treatment plants, and dairies.
PNG-07-005	1	Reducing California Industrial Natural Gas Consumption Through Advanced Biomass Gasification	Diversified Energy Corporation	Samoa, CA	$500,000	$500,000	To demonstrate an integrated biomass gasification project to convert waste wood fines into usable syngas via advanced biomass molten metal-based gasification.	Demonstrate that the technical process can use a variety of biomass feedstock with heating value between 6,000 - 10,000 Btu/lb and moisture content between 0 and 50%. Generate replacement syngas greater than 5,000 scf/hr and 175 btu/scf to replace natural gas for industrial process heating and drying applications Operate the project system to replace natural gas injection to the thermal oxidizer flare to realize reduction in natural gas consumption
PNG-07-006	1	Integrated CHP Using Ultra-Low-NOx Supplemental Firing	Gas Technology Institute	La Puente, CA	$501,437	$673,283	To develop a cost-effective gas turbine-based CHP system that improves overall efficiency and meets CARB 2007 emission standards without catalytic exhaust gas treatment.	Demonstrate the system at a host site in California Achieve CARB 2007 emissions standards Achieve 84% (HHV) system efficiency Produce a pre-engineered cost-effective CHP package Validate the system in the GTI laboratory
Totals:	24 agreements		25 projects	24 projects in CA	$22,792,039	$16,989,987		

Table B-2.3: Description of Energy-Related Environmental Research Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
500-05-026	1	Natural Gas Variability in California: Environmental Impacts and Device Performance	Gas Technology Institute	Berkeley, CA	$4,336,690	$0	To provide information to policymakers, regulators and industry such as on the potential safety, performance, emissions, and air quality impacts of increased variability in the California NG supply, and specifically related to the use of LNG. The study will examine classes of industrial and commercial natural gas burners along with their combustion control systems, residential appliances, and other burners as identified. Air quality impacts will be evaluated for outdoor air. Interchangeability considerations will include performance and safety, in addition to environmental impacts of LNG and other substitute gases relative to traditional NG formulations. This interchangeability information will provide a means to operate the most flexible and safest NG system with the widest gas supply options for California customers.	Test sensitive classes of burners and typical combustion control systems under defined boundaries of NG and LNG supply options to determine changes in performance and emissions
								Develop test protocols by which classes of burners can be evaluated for robustness in meeting California performance and emission requirements
								Quantify baseline (using currently delivered NG) emissions and performance of in-use home appliances and burners
								Use photochemical and transport models to evaluate the effect of variable NG and LNG supplies on ozone and other air quality parameters in the South Coast Air Basin of Southern California
								Define performance limits for analyzing combustion system performance, based on changing fuel composition
								Analyze and report the results of testing with selected classes of burners and review the implications relative to California energy efficiency and emissions objectives
								Use combustion modeling to assess burner performance and emissions for interchangeability purposes (relative to changing fuel gas) when maximizing the flexibility of NG supply options for California consumers
								Prepare modeling strategies for classes of burners that address impacts of NG changes and the implications regarding the interchangeability of the fuel gases
								Develop the correlation between emissions of air pollutants and one or more interchangeability parameters
								Establish testing needs by burner class and evaluate potential on California energy use and air quality goals

Table B-2.3: Description of Energy-Related Environmental Research Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
500-08-034	1	Gaseous Fuel Interchangeability Criteria Development	UC Irvine	Irvine, CA	$1,132,714	$82,000	To develop natural gas interchangeability criteria (GFIC) that will help decision-makers, including government agencies, industrial/commercial combustion system operators, and manufacturers, to predict fuel variation impacts before provisioning for these different fuels. The project will define how these parameters such as combustion efficiency, combustion device operability, and emissions are influenced by fuels that lie outside of present-day fuel specifications so they will meet future specifications for pipeline transmission.	Provide validated design tools for OEMs to use in evaluating fuel flexibility of their current and future products to meet specifications for transmission in pipelines. Develop design tools for OEMs to use in evaluating fuel flexibility of their current and future products. Validate, on a limited basis, the design tools developed Develop and provide data associated with potential alternative fuels that can be used by Original Equipments Manufacturers (OEMs) and utilities to establish technology requirements for systems designed for such fuels
500-09-032	1	Improving Regional Climate Models: Aircraft Collection of Data	Pacific Northwest National Laboratory	Mcclellan Park, CA	$800,000	$0	To improve the accuracy of regional climate models is essential for projecting reliable climate change trends and also for making appropriate adaptation plans for the natural gas system.	Perform airborned testing using a research aircraft Preapre metadata that includes quality-controlled datasets for all the instruments used and make the data available to the scientific community Collect could physics measurements for paramenters such as size of droplets, number of droplets, and thermodynamic state of these droplets (i.e., liquid water, snow, ice)
500-09-034	1	Potential Impacts from Geologic Carbon Sequestration on Groundwater Resources in Central Valley of California	Lawrence Berkeley National Laboratory	Berkeley, CA	$490,000	$0	To improve understanding of how geological sequestration of CO2 in the San Joaquin Basin will affect groundwater resources for the region's agricultural sector so that CO2 from NG power plants can be in future carbon reduction methods.	Evaluate the impacts of basin pressure increases due to large volume CO2 injection on subsurface and surface water resources in the context of the San Joaquin Valley Research basin pressure changes in response to historic hydrocarbon production in the southern San Joaquin Valley as an analog to CO2 storage.
500-09-035	1	The potential of biochar soil amendments as a carbon sequestration method in California agriculture	UC Davis	Davis, CA	$700,000	$0	To identify and evaluate the use of pyrolyzed biomass as organic soil amendments, in order to understand and effectively demonstrate the role of biochar in GHG emission reduction, soil fertility, and plant productivity in California agriculture as a potential for CO2 sequestration from NG sources.	Determine the GHG emissions following biochar soil amendments. Examine the fate and stability of biochar in soils. Analyze the chemical structure and physical interactions of biochar in soils.

Table B-2.3: Description of Energy-Related Environmental Research Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
500-09-042	1	Healthy Homes - Exposure to Unvented Combustion Gases	Lawrence Berkeley National Laboratory	Berkeley, CA	$2,263,300	$0	To develop the science for reducing health risks from indoor air pollutant exposures from unvented and improperly vented natural gas combustion appliances, and to conduct targeted research to enable synergistic improvements in both energy efficiency and indoor air quality in California homes with gas appliances.	Quantify combustion-associated pollutant levels in a large number of occupied California homes under normal operation Investigate and quantify the relative importance of factors that contribute most substantially to exposures of unvented combustion gases Document the developed approaches and results in a technical publications Develop approaches to quantifying exposures to unvented combustion gases and to identify key sources
500-10-038	1	Evaluation and Improvement of Particulate Matter Measurement from NG Power Plants	UC Riverside	Riverside, CA	$680,000	$0	To improve the understanding of the air quality impacts and uncertainty in the permitting levels used to cite NG power plants by improving the PM emissions estimates and measurement methods from NG plants.	Evaluate the accuracy and precision of current and proposed particulate matter test methods, especially those methods aimed at condensable particulate matter
500-10-040	1	Energy, Air Quality, Water and Climate Change Co-Benefits of Renewable Generation and Fuels Roadmap	Advanced Power and Energy Program (UC Irvine)	Irvine, CA	$30,010	$0	To develop a roadmap identifying the state of knowledge, research gaps, and recommended research pathways to quantify the air quality benefits/cost of renewable generation and of alternative fuels and the energy. The roadmap will address impact on the natural gas system.	Conduct research and host a workshop to identify the proven and/or expected performance of alternative energy and fuel technologies Conduct research and host a workshop to identify methods to analyze energy, environmental and climate change co-benefits Develop a roadmap that identifies the state of knowledge, research gaps, and recommended research pathways to evaluate potential air quality impacts and energy, climate change and water co-benefits of the use of traditional, alternative and renewable natural gas in California

Table B-2.3: Description of Energy-Related Environmental Research Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
500-10-052	1	Innovative Air Cleaner for Improved IAQ and Energy Savings	Lawrence Berkeley National Laboratory	Berkeley, CA	$244,699	$0	To improve indoor air quality (IAQ) through improved air cleaning technology to substantially reduce the energy required for building ventilation during the operation of natural gas burning appliances and other building systems.	Design, build, test, and demonstrate a new integrated-technology air cleaner (ITAC) that can improve IAQ, in many cases with substantial reductions in ventilation rates and energy consumption
	12	Building Air-Tightness Through Appliance Venting Standards			$382,909	$0	To improve energy efficiency while maintaining occupant health and safety by reducing the barriers to increased air tightening posed by natural gas combustion appliances.	Take the diagnostic procedure developed to American Society for Testing and Materials (ASTM) Performance of Buildings (E6) Committee/Subcommittee for incorporation into their existing guide (E1998-02) and to Title 24 for inclusion as a standard method of test. Disseminate project results in the form of a Diagnostic Test and Air Tightening Guide and input to standards. The information generated will describes the diagnostic procedures and guides air tightening activities while maintaining proper combustion appliance venting. Perform field tests to evaluate the new test method on up to five local houses with various wind exposures. Once the method is deemed reliable, extend the test results over a broad range of climates and house/vent combinations using computer software. Develop a diagnostic method for determining probable maximum depressurization and the likelihood of backdrafting and spillage. Perform a literature review, which will identify recent advances in combustion safety knowledge with particular emphasis on vent system resistance, wind effects, and simulation of vent system performance.

Table B-2.3: Description of Energy-Related Environmental Research Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
500-11-016	1	Assessment of Bay Area Gas Pipeline Vulnerability to Sea Water Intrusion	UC Berkeley	Berkeley, CA	$425,000	$0	To: (1) conduct a comprehensive analysis of the vulnerability of gas pipelines in the Sacramento and San Joaquin Delta regions to sea water intrusion (the research team will develop useful risk assessment information such as regional maps of the gas pipeline locations); (2) conduct a statewide scoping study; (3) analyze various cost-based adaptation strategies to be used for siting gas pipelines; and (4) develop modeling tools for establishing environmental baselines and determining the environmental impacts of salt water intrusion on future pipelines.	Map the location of gas pipelines to determine which pipelines are at risk within the San Francisco Bay Metropolitan and Sacramento-San Joaquin Delta regions.
								Develop tools capable of establishing environmental baselines and determining environmental impacts on future pipelines.
								Identify sensitive ecosystems at risk of storm events and flooding using simulations of flooding and inundation to understand the processes of gas pipeline inundation and quantify its environmental impacts.
								Develop a preliminary statewide understanding of the vulnerability of the natural gas system to sea water intrusion and flooding.
								Demonstrate, assess, and determine cost strategies for armoring, decommissioning, and relocating the pipelines, leading to new generalized suitability equations for siting gas pipelines under sea water intrusion.
500-11-022	1	Low-Cost High Sensitivity NOx Sensors	Lawrence Livermore National Laboratory	Livermore, CA	$600,000	$0	To develop NOx sensor technology that can be used to limit NOx emissions from natural gas-powered distributed generation.	Building prototype sensors and evaluating the response in a simulated DG environment in the laboratory
								Developing and testing a “final” third generation prototype
								Refining the initial sensor package to optimize the sensor for second generation testing
								Selection of a high priority DG technology and definition of the operating environment and first generation sensor design
								Moving the second generation prototype sensors from laboratory testing to a “real world” testing environment

Table B-2.3: Description of Energy-Related Environmental Research Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
500-11-024	1	Assessment of Potentially Deleterious Effect of Geologic Carbon Sequestration Operations on Groundwater Quality	Lawrence Berkeley National Laboratory	Berkeley, CA	$600,000	$0	To perform laboratory and computer modeling that will support effective decision-making regarding the risk of water resource degradation due to long-term CO2 storage activities and validate CO2 sequestration from NG power plants as a future option in meeting the state's GHG reduction goals.	Improved reactive transport models from research conducted by this project that can be applied to further evaluate the mobilization, fate (processes that transform chemicals in the environment), and transport of trace metals in groundwater by CO2 leaks from CCS operations in California
								Determine the impact of organic material on metal mobilization and microbial activity within aquifers.
								Determine the most probable mechanisms of water quality impacts as a result of CO2 leaks
								Evaluate the extent to which these water quality impacts reverse themselves upon depressurization during transport to the surface.
								Determine the impact of elevated CO2 groundwater on metal within aquifers
								Assess the quantity and quality of supercritical CO-leachable organic material from a typical reservoir cap.
								Assess mineral-trace metal associations in typical aquifers near areas deemed most suitable for Carbon Capture and Storage (CCS) operations in California.
500-11-027	1	Evaluation of Opportunities to Mitigate Fugitive Methane Emissions from the California Natural Gas System	Lawrence Berkeley National Laboratory	Berkeley, CA	$1,100,000	$0	To identify control strategies that provide the highest ratios of mitigated emissions to cost of implementation (Rufo et al., 2003). This work will be conducted to assist the natural gas industry in reducing emissions in a cost effective manner to comply with the greenhouse gas (GHG) emission requirements of AB-32.	Experimentally determine emissions for an appropriate subset of infrastructure components that were not captured in previous work.
								Work with industry and utility partners to identify missing information on sources of emission and possible control measures.
								Conduct initial experiments that evaluate the reduction in emissions from selected mitigation measures.
								Use available information to estimate bottom-up natural gas emissions at the facility-scale for comparison with atmospheric validation efforts.
								Estimate the likely costs and emissions control benefits of different mitigation measures.
500-12-006	1	Top-Down Quantification of Methane Emissions from California's Natural Gas System	UC Davis	Davis, CA	$900,000	$0	To quantitatively survey methane emissions across the sub-sectors of California’s natural gas infrastructure, providing baseline measurements that identify promising areas for mitigation activities and provide a means to verify their success.	Development and demonstration of methods to quantify natural gas emissions for each important sub-sector of California’s natural gas sources
								Quantification of natural gas emissions across important sub-sectors within sample regions of California

Table B-2.3: Description of Energy-Related Environmental Research Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
500-12-009	1	Impact of Natural Gas Composition on the Performance and Emission of Heavy/Medium-Duty Natural Gas Vehicles - Phase 2	UC Riverside	Riverside, CA	$400,963	$120,000	To address issues relating to the impacts of using a broader range of natural gas compositions on vehicles, such as those that may be expected with greater introduction of gases with higher or lower Wobbe than California traditional gases. This program will evaluate the impact of various NG compositions on the performance and emissions of NG powered heavy- and medium-duty vehicles. Testing will address issues such as the impact of the different LNG blends on fuel economy, operability and emissions of air pollutants.	Facilitate the integration of broader and more diverse sources of NG into the NG gas system for use in vehicles. Reduce the environmental impacts of broader and more diverse sources of NG when used in vehicle applications. Ensure that new and existing NG engines can operate effectively and with no environmental disadvantages when using broader and more diverse sources of NG.
500-12-010	1	Investigations of Potential Induced Seismicity Related to Geologic Carbon Dioxide Sequestration in California	Lawrence Berkeley National Laboratory	Berkeley, CA	$575,423	$0	To identify and assess existing data and rock core samples to determine if they can be used to address the problem of induced seismicity related to CO2-injection by investigating potential seismic hazards related to geologic sequestration projects in California. Determine if long term sequestration of CO2 from natural gas power plants is a future option in meeting the state's GHG reduction goals.	Assess available data and rock samples to address the most pressing questions about the potential for geologic carbon sequestration to cause induced seismic events or exacerbate Perform laboratory analyses and experiments on available samples and create computer simulations of potential events based on the data sets.
PIR-11-024	1	Wind Barriers to Mitigate Wind Effects on Air-Cooled Condensers	Maulbetsch Consulting	Menlo Park, CA	$749,577	$97,000	To advance understanding of how wind barriers affect air flow around and through air cooler condensers and how such performance can be improved for natural gas-fired power plants.	Develop guidance on the specification, design, and installation of effective wind barriers for ACCs at power plants. Success within the project will be defined as obtaining consistent results from mathematical modeling, physical modeling, and field testing, and translating those results into a set of clear, applicable guidelines.
Totals:		17 agreements	18 projects	18 projects in CA	$16,411,285	$299,000		

Table B-2.4: Description of Natural Gas Related Transportation Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
500-07-012	1	Effect of Natural Gas Fuel Composition on Vehicle Performance and Emissions	UC Riverside	Riverside, CA	$400,000	$50,000	To address issues relating to the impact of using a broader range of natural gas compositions, such as those that would be expected with greater introduction of LNG. This program will evaluate the impact of new NG compositions on the performance and emissions of NG powered equipment and engines.	Reduce environmental impacts of broader and more diverse sources of NG when used in vehicle applications
								Facilitate the integration of broader and more diverse sources of NG into the NG gas system for use in vehicles
								Ensure new and existing NG engines can operate effectively and with no environmental disadvantages when using broader and more diverse sources of NG
500-08-022	1	The Advanced Natural Gas Fuel Tank Project	University of Missouri, Columbia	Columbia, MO	$1,000,000	$500,000	To develop a replacement for the bulky, heavy-walled compressed NG tanks currently used in NG vehicles. The project will develop a flat, solid-state, light-weight tank that stores NG in adsorbed form, providing natural gas vehicles with an increase in storage capacity and driving range while reducing weight and cost, enabling a more competitive market for NG vehicles. Briquettes produced from corncorbs will be used inside the tank to adsorb NG, with storage capacity meeting the Department of Energy target: 180 times more gas per volume than under standard temperature and pressure conditions.	Reduce on-board storage tank weight.
								Develop advanced tank to increase driving range to 300 miles.
								Enable flat tank design based on reduction in storage pressure.
								Develop method to reduce storage pressure from 3600 psi to 500 psi.
500-08-058	1	Natural Gas Vehicle Research: Industry Applications	National Renewable Energy Laboratory	Golden, CO	$300,000	$0	To provide research and analysis to support engine development and vehicle integration, fueling infrastructure and storage. The research will identify the highest value current and future RDD&D efforts required to build a sustainable NGV market within California.	Producing NGV demand and supply information.
								Establishing collaborative links with vehicle manufacturers and suppliers.
								Providing a forum for OEM/supplier liaisons and dialog (NGVTF).
								Tracking and analyzing current NG RDD&D industry activities .
								Consolidating private and public stakeholder consensus guidance on implementation of NGV RD&D

Table B-2.4: Description of Natural Gas Related Transportation Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
500-09-004	1	Purification and Liquefaction of Biomethane Landfill Gas for Transportation Fuel	Gas Technology Institute	Livermore, CA	$992,903	$0	To develop advanced transportation technologies that reduce pollution and greenhouse gas emissions and benefit natural gas ratepayers.	Complete component designs for the liquefier, onsite aboveground cryogenic storage tanks, and fuel dispending equipment and related facilities.
								Design a biogas clean-up system for removal of contaminants such as sulfur, water, organo-silanes, halogens and other hydrocarbons, carbon dioxide, and nitrogen to produce feed gas for the liquefier.
								Integrate design components into a site specific system that includes fuel gathering, cleansing, processing, liquefaction, compression, distribution, dispensing, and transportation capabilities.
								Complete the site specific requirements and design as required to prepare the Waste Management, Inc. Altamont Landfill facility for the addition of the gas clean-up and liquefaction system.
								Install equipment and complete site improvements.
500-09-006	1	California Transportation Fuels Crops Development and Demonstration	California Department of Food and Agriculture	Five Points, CA	$993,284	$0	To advance the scientific understanding of crop-based biofuel production options suitable for application across California's diverse cropping regions and growing conditions.	Demonstrate potential energy and industrial crops under commercial conditions (focusing on crops that may use marginal lands and that minimize environmental externalities)
								Determine the suitability of these crops for various energy and industrial markets such as renewable natural gas feedstock.
500-09-051	1	Alternative Fuels and Vehicle Compatibility Research	UC Riverside	Riverside, CA	$1,200,000	$0	To address issues relating to the impact of using a wider range of alcohols on the emissions and performance of the current and future California vehicle fleet. It will evaluate various mixtures of mixed-alcohol fuels in both conventional vehicles and FFVs, with an emphasis on emissions, performance, and fuel system compatibility. Phase I will review on-going studies, assemble advisory/stakeholder groups, and identify appropriate vehicle technologies and fuel formulations. Phase II will test tailpipe emissions and examine issues such as vehicle/fuel compatibility.	Facilitate the integration of broader and more diverse sources of mixed alcohols for vehicle transportation.
								Reduce environmental impacts of broader and ore diverse sources of mixed alcohols when used in vehicle applications
								Ensure that new and existing vehicles can operate effectively and with no environmental penalty when using broader and more diverse sources of mixed alcohols.

Table B-2.4: Description of Natural Gas Related Transportation Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
500-10-039	1	California Initiative for Large Molecule Sustainable Fuels	UC San Diego	San Diego, CA	$2,000,000	$1,999,998	To promote research and development for sustainable, low carbon, drop-in large molecule liquid fuels to meet California's future renewable natural gas needs.	Develop economically viable technologies to collect and purify biofuels from plant and algal biomass.
								Engineer value-added products into producer organisms for non-biofuel applications, a further critical factor in economic viability of biofuels.
								Develop a suite of genetic tools for non-food biomass organisms for biofuel applications.
								Develop new strategies to recycle wastewater and associated nutrients and minimize biofuel waste streams.
								Develop high-volume capacity processes for rapid selection and evaluation of biofuel organisms.
								Develop a long-term strategy for the identification and development of new research areas and technologies that may be useful for the sustainable production of large molecule sustainable fuels.
								Develop robust life cycle analysis of large molecule biofuel production for use in renewable natural gas products.
								Develop biotechnology strategies to protect new biofuel crops (plants and algae) against pests and other unwanted wild organisms.
500-10-053	1	Natural Gas Engine and Vehicle Integration Research	National Renewable Energy Laboratory	Golden, CO	$4,250,000	$13,100,000	Advancement of advanced alternatively-fueled transportation engines and vehicles to reduce GHG emissions and displace imported petroleum that can operate on natural gas and renewable natural gas.	Demonstrate the integrated engine and chassis in real-world operation for 6-12 months.
								Develop a natural gas fueled engine that has no greater than 20% fuel economy penalty compared to a comparable conventionally-fueled diesel engine.
								Develop a new natural gas fueled medium- or heavy-duty engine that meets or exceeds 2010 emissions requirements
								Advancement of advanced alternative fueled transportation engines and vehicles to reduce GHG emissions and displace imported petroleum.

Table B-2.4: Description of Natural Gas Related Transportation Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
500-11-004	1	Production of Substituted Natural Gas from the Wet Organic Waste by Utilizing PDU-Scale Steam Hydrogasification Process	UC Riverside	Riverside, CA	$649,214	$200,000	To further develop a promising waste-to-energy technology known as the Steam Hydrogasification Reaction Process (SHR) process. The process, which has been successfully demonstrated at process demonstration unit (PDU) scale to produce syngas, will be extended to produce substituted natural gas.	Demonstrate and validate the production of substituted natural gas with SHR integrated with WGS process from the pretreated feedstock. The throughput will be 0.1 ton per day (10 pounds per hour) of feedstock.
								Demonstrate and validate the feedstock pretreatment system to produce a pumpable slurry from the comingled biomass/ biosolids, food waste and green waste that will be used in the SHR process, achieving a feedstock supply rate of 0.1 ton per day (10 pounds per hour) for 24 hours of continuous operation.
								Complete the basic engineering design for a 5 tons per day scale pilot plant using key information obtained through the PDU scale demonstration.
								Complete the comparison life cycle energy production cost between different technologies of producing substituted natural gas from wet organic wastes.
500-11-014	1	Improved Renewable Natural Gas Production by Steam Hydrogasification with Carbon Capture	UC Riverside	Riverside, CA	$1,400,536	$0	To further develop and demonstrate at bench scale a thermo-chemical process that combines a carbon dioxide sorption enhanced steam hydrogasification reaction (SE-SHR) with a water gas shift reactor to produce high levels of substituted natural gas using biomass resources in California.	Evaluate the process economics and energy balances by developing an integrated process flow and economic model with in-house engineering software packages.
								Complete a basic engineering design for a pilot plant using key information developed under this Agreement, allowing for both technical and economic feasibility analyses of a commercial scale process.
								Demonstrate and validate the production of SNG with the SE-SHR process. The demonstration will be performed at the bench-scale SE-SHR Circulating Fluidized Bed (CFB) reactor.
500-11-015	1	Alternative Fuels Natural Gas Infrastructure Compatibility	UC Riverside	Riverside, CA	$1,200,000	$0	To improve and advance infrastructure and fuels technologies that demonstrate potential to reliably supply alternative transportation fuels in and for California, such as natural gas and renewable natural gas.	Test fuel infrastructure with fuel samples to determine material compatibility.

Table B-2.4: Description of Natural Gas Related Transportation Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
500-12-008	1	Development of Natural Gas Vehicle Research Roadmap	National Renewable Energy Laboratory	Golden, CO	$313,000	$0	To support the Energy Commission in identifying and prioritizing research activities, while serving as a guidepost for national NG vehicle activities. Evaluating key barriers, benefits, and risks to increased use of natural gas in transportation and incorporating these into a CEC vision (roadmap) will ensure maximiation of benefits and avoidance of negative impacts to environmental, energy, and economic goals.	Research and articulate technologies, trends, and priorities in the area of natural gas vehicles.
500-12-012	1	Low NOx Natural Gas Engine Development for Heavy-Duty Vehicles	Southcoast Air Quality Management District	Diamond Bar, CA	$2,000,000	$0	To optimize after-treatment technology designs, after-treatment configurations, engine tuning, and engine management practices for heavy-duty natural gas engines. The objective is to maximize NOx reductions while continuing to meet or exceed all applicable standards for hydrocarbons, non-methane hydrocarbons, carbon monoxide, and PM, and without incurring a fuel economy penalty. A NOx emission rate between 0.02 (a 90% reduction from the 2010 standard) and 0.05 g/bhp-hr is considered achievable through the proposed research.	Achieve emissions targets of 0.02 g/bhp-hr NOx, 0.01 g/bhp-hr particulate matter (PM), 0.14 g/bhp-hr Hydrocarbon (HC), and 15.5 g/bhp-hr Carbon Monoxide (CO) or lower as determined by the heavy-duty engine federal test procedure (FTP). Keep exhaust Ammonia (NH3) emissions as low as achievable, preferably 10 parts per million or lower. Develop engines that achieve 20% or lower engine thermal efficiency penalty or fuel economy penalty when compared to 2010 U.S. EPA and CARB certified diesel engines in similar duty cycle.

Table B-2.4: Description of Natural Gas Related Transportation Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
PIR-08-045	1	Lower Cost High Performance and High Efficiency Pilot-Ignited Directly Injected HD Natural Gas Engine	Westport Power, Inc.	Vancouver, BC (Canada)	$998,844	$998,844	To further reduce the initial ownership and operating costs of HPDI technology, and to explore selected efficiency improvements. To improve engine performance (BMEP) and robustness to fuel quality variations, including renewable natural gas.	Reduce HPDI fuel consumption by 5% from current levels over an European Stationary Cycle (ESC) test which will lead to an approximately 20% lower ESC averaged fuel consumption compared to today's spark ignited (SI) engine. Reduce the heavy-duty HPDI engine system component costs (fuel system, in particular injectors and fuel rail pressure control module, and exhaust after treatment) by 20% compared to current design. Improve engine operating robustness to natural gas quality and achieve satisfactory engine operation for a wider range of fuel quality. Maintain emissions below 2010 Environmental Protection Agency (EPA) emissions targets (0.2 grams per brake horse power-hour [g/bhp-hr] Oxides of Nitrogen [NOx], 0.01 g/bhp-hr particulate matter [PM], 0.14 Non methane Hydrocarbon g/bhp-hr) while improving on greenhouse gas emissions by approximately 20% compared to today's SI engines. Improve HPDI power density by 10% (up to 21.5 bar) from current levels which will lead to an engine power density that is approximately 25% higher compared to today's SI engines.
PIR-08-047	1	Algae OMEGA: Offshore Membrane Enclosures for Growing Algae	NASA Ames Research Center	San Francisco, CA	$793,576	$6,424	To demonstration that OMEGA is a technologically and economically viable system for growing algae for biofuels, while providing other valuable products and services once the renewable natural gas has been produced.	Demonstrate long-term performance of FO membranes for dewatering algal biomass, concentrating nutrients, and tertiary-treatment of wastewater. Demonstrate that an OMEGA design can withstand up to 6 months of deployment without material for functional failures. Determine the growth rates and yield of algae in OMEGAs under lab and field conditions using secondary effluent and optimized media for oil production.

Table B-2.4: Description of Natural Gas Related Transportation Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
PIR-12-002	1	Green Waste to Renewable Natural Gas by PyroBioMethane	Anaergia Services	Carlsbad, CA	$395,121	$437,093	To demonstrate that green waste can be converted to LNG or CNG through a pyrolysis process called PyroBioMethane (PBM), which reduces the mass of green waste for disposal and outputts two value products in the bio-char and condensate. The bio-char holds all of the nutrients that were in the original green waste feed, giving it value as a potential fertilizer. The condensate, which is generated by condensing the gas caused in pyrolysis, is rich in volatile solids that can be fed to an anaerobic digester and co-digested with other substrates to make biogas.	Reduce hauling and disposal fees for green wastes. Generate 7,000 ft3 of biogas per ton of green waste fed By extension show that 55 gallons of LNG can be made from one ton of green waste Retain all nutrient value of the green waste in the resultant bio-char from pyrolysis Achieve a 50% mass reduction of green waste through pyrolysis
PIR-12-007	1	Renewable Natural Gas Production with Value-Added Fertilizer Co-Product	CleanWorld	Sacramento, CA	$820,000	$690,830	Improve the economic feasibility of anaerobic digestion systems that create biomethane and deploying an innovative approach to producing fertilizer products from anaerobic digester effluent.	Reduce petroleum dependence by improving economics for renewable natural gas projects. Improve process-related effluent processing economics. Reduce GHG emissions by up to 2,270 tons of CO2 equivalents per year by offsetting nitrogen-based fertilizers with natural and organic fertilizers. Stimulate economic development in California by developing a replicable plan for fertilizer production at AD projects. Demonstrate commercial-scale effluent processing at a biodigester and CNG production facility. Provide natural fertilizer products at competitive market costs to local growers.
PIR-12-014	1	Benefits of Dynamic Skip Fire for Improved Natural Gas Engine Performance	UC Berkeley	Berkeley, CA	$600,000	$125,600	To improve fuel economy on natural gas engines using advanced skip firing technologies in combination with cylinder deactivation under naturally aspirated and boosted intake.	Demonstrate fuel economy saving of 20% on a GM 6.2 Liter engine with skip fire technologies under 2-cycle Corporate Average Fuel Economy (CAFE) formula Improve the power density using boosted intake conditions Meet emission standards with a 3-way catalyst

Table B-2.4: Description of Natural Gas Related Transportation Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
PIR-12-017	1	Advanced 6.7 Liter Natural Gas Engine Development	Gas Technology Institute	Des Plaines, IL	$1,000,000	$2,164,735	To design, develop, and demonstrate a pre-commercial spark ignited natural gas engine with ultra low emissions, high performance, and best in class fuel economy in specific Class 3 through 7 truck and bus duty cycles.	Demonstrate a peak rating of 260 hp and 660 lbs.ft. peak torque Improve fuel economy by 5 to 10% when compared to CWI's 5.9 liter lean burn spark ignition natural gas engine that CWI sold in the North American market through 2009 Demonstrate GHG emissions (CO2, CH4 and N2O) that will enable emission certification at or below the U.S. EPA 2017 GHG emission standards Design, develop, and demonstrate (on dynamometer) an Alpha stage 6.7 liter medium duty natural gas engine that can be certified at or below U.S. EPA / CARB 2013 emission standards (g/bhp-hr): 0.20 NOx, 0.14 NMHC, 0.01 PM, 15.5 CO.
PIR-12-020	1	Carbon Dioxide Based Co-Products from Renewable Natural Gas Fuel Production	UC Riverside	Riverside, CA	$359,847	$0	To develop a cost-effective technology for CO2 conversion into a commercially valuable co-product such as methanol or Dimethyl Ether (DME); and develop a combined CO2 separation and conversion technology that converts the CO2 into a commercially valuable co-product such as potassium carbonate.	Develop and optimize a technology for the cost-effective synthesis of potassium carbonate from CO2 recovered from RNG fuel production processes. Develop and optimize a technology for the cost-effective synthesis of methanol and DME from CO2 recovered from RNG fuel production processes.
PIR-12-021	1	Interra Reciprocating Reactor to Produce Low-Cost Renewable Natural Gas	Interra Energy, Inc.	San Diego, CA	$818,147	$228,146	To demonstrate the fundamental merits of the Reciprocating Reactor's design by producing the highest quantity of biochar on an input/output basis and the highest end-quality gas on an energy density basis (btu/scf), without the use of chemical catalysts, separate gas upgrading processes, external heat input, or air/oxygen injection for combustion heat makeup.	Determine the maximal bulk material particle size the system can process without a jamming or lock-up event and determining where that blockage will likely occur. Determine how the additional supporting weight of the inner-reactor tube and feed screw affect torsional requirements of the reciprocating auger drive system. Determine maximum fill level of heat-exchange zone of reactor. Determine the appropriate feed/reciprocating auger ratio under cold conditions to allow for estimation of ratio under "hot" operational conditions.
Totals:	21 agreements		21 projects	15 projects in CA	$22,484,472	$20,501,670		

Table B-2.5 Description of Natural Gas Pipeline Integrity Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
500-10-044	1	Natural Gas Pipeline Research - Innovative Monitoring Technologies	UC Berkeley	Berkeley, CA	$478,457	$0	To develop prototypes of next-generation low cost sensors that have the potential to significantly improve the safety and security of natural gas pipelines, without impacting operations. Some characteristics of the next generation sensors are low cost, monitoring and inspection of pipelines without disrupting service, provision of timely condition-based maintenance, and electronic sensors that can communicate data in electronic format and allow for easy storage. The stored data can be use for audit purposes and data analyses that may lead to early forecasting of imminent failures.	Field test the sensor package in a utility setting to obtain real world performance data. Fabricate the individual sensors and integrate them into a deployable sensor package. Design low-cost sensors for use in gas pipelines to measure operational characteristics including pressure, flowrate, and vibrations due to external sources. Lab test the sensor package to refine system operation and reliability prior to field demonstrations.
500-10-050	1	Natural Gas Pipeline Research - Best Practices in Monitoring Technology	Gas Technology Institute (GTI)	Des Plaines, IL	$480,000	$0	To assess the state of pipeline integrity assessment and monitoring technology currently in use in California, identify available but not in use and emerging technology that could be developed in two to four years, and to develop an implementation plan to enhance the safety and operations of the natural gas pipeline system in California.	Evaluate new and emerging technology which could be implemented to improve pipeline system integrity and status monitoring that is not currently in use. Generate a testing, deployment, and implementation plan for available or near commercial technologies that address the identified gaps. Assess currently available technology which could be implemented to improve pipeline system integrity and status monitoring that is not currently in use. Define the current state of technology in California related to underground natural gas pipeline assessment, monitoring and integrity management.

Table B-2.5 Description of Natural Gas Pipeline Integrity Projects

Agreement	Project	Project Title	Recipient	Location	NG Funding	Match Funding	Goal	Project Objectives
PIR-12-009	1	Commercialization of ILI Technology which Accurately Detects, Locates, and Measures Pipeline Girth Weld Defects	Diakont Advanced Technologies, Inc	San Diego, CA	$1,000,000	$1,600,000	To complete the development of a robotic operational defect inspection system module that will perform in-line inspection of girth-welds on piggable and unpiggable carbon steel pipelines of nominal pipe size 28"-56". The project will take the technology from its current prototype level to a commercial level of performance.	The primary objective of the project is to develop and demonstrate a non-destructive in-line inspection solution for detecting, measuring, and characterizing operational and construction defects within pipeline system girth welds and heat affected zone regions.
PIR-12-013	1	Real-time Active Pipeline Integrity Detection (RAPID)	Acellent Technologies, Inc	Sunnyvale, CA	$622,622	$0	To maintain the safety of the pipeline system, accurately measure a crack in a pipeline while it is in the ditch, transmit pipeline data to the back office, reduce structural inspection costs, avoid unplanned pipeline failure and move from schedule-driven to condition-based maintenance. The recipient will deliver a Real-time Active Pipeline Integrity Detection system for new and existing pipelines to achieve these goals.	Assess damage information from structural anomalies including fatigue cracks in highly loaded metallic fittings and impact damage. Identify invisible and invisible damage in metal and non-metallic structures Obtain real-time information on the integrity of a structure during service Provide an easy to used inspection tool for maintenance personnel
Totals:		4 agreements	4 projects	projects in CA	$2,581,079	$1,600,000		

Table B-3.1: Quantitative Benefits of Energy Efficiency Projects

Agreement	Project	Project Title	Technical Potential (therms/year)	Market Penetration Estimate/Assumption	Benefits Estimates		
					Energy Savings (therms/year)	Energy Cost Savings ($/year)	GHG Reductions (metric tons/year)
PIR-08-023	1	Improving Efficiency of Spark Ignited, Stoichiometrically-operated Natural Gas Engines	1,300,000	1%	13,000	$7,280	69
PIR-09-004	1	Integrated Waste Heat and Wastewater Recovery DOME for Food Processing Applications	30,000,000	1%	300,000	$168,000	1,592
PIR-10-017	1	Supercritical CO2 Cleaning and Sterilization of Commercial / Industrial Textile	Unkown	Contractor Estimate	22,000,000	$12,320,000	116,754
PIR-12-024	1	ZNE Demonstration-Integration of Dynamic Daylighting and Passive Cooling/Heating for High Return on Investment	Unknown	Savings from the demonstration project itself	2,316	$1,612	12
PIR-12-026	1	Innovative Low-Energy Occupant-Responsive Controls for Heating, Ventilation and Air Conditioning Systems	13,000,000	25%	3,250,000	$2,262,000	17,248
PIR-12-028	1	Advanced Envelope Systems for Factory Built Homes	1,420,000	1%	14,200	$12,794	75
PIR-12-030	1	Improve Energy Efficiency of Hot Water Distribution Systems in Multifamily Buildings	134,000,000	1%	1,340,000	$1,207,340	7,111
PIR-12-031	1	Small and Medium Building Efficiency Toolkit and Community Demonstration Program	30,200,000	8%	2,500,000	$1,740,000	13,267
500-08-023	1	Energy and Water Recovery with Transport Membrane Condenser	Unkown	Contractor Estimate	42,000,000	$26,376,000	222,894
500-08-037	1	Waste Heat Recovery from Corrosive Industrial Exhaust Gases	Unkown	Contractor Estimate	2,400,000	$1,344,000	12,737

Table B-3.1: Quantitative Benefits of Energy Efficiency Projects

Agreement	Project	Project Title	Technical Potential (therms/year)	Market Penetration Estimate/Assumption	Benefits Estimates		
					Energy Savings (therms/year)	Energy Cost Savings ($/year)	GHG Reductions (metric tons/year)
500-08-051	1	Advanced Radiant HVAC Systems for California Homes	100,000,000	10%	10,000,000	$9,010,000	53,070
500-08-060	1	Residential Water Heating Program	Average annual savings from new residential construction, 2009-2025.		5,375,000	$1,188,757	28,525
500-09-044	1	Advanced Foodservice Appliances for California Restaurants	57,400,000	30% to 50% (varies by appliance)	23,200,000	$1,614,720	123,122
500-10-015	1	Large Scale Residential Retrofit Program	Unknown	Savings from the demonstration project itself	2,723	$2,453	14
500-10-052	7	Reducing Waste In Residential Hot Water Distribution Systems	Supposing project results in new Title 24 standard that reduces residential water heating by 1% at statewide penetration.		21,110,000	$19,020,110	112,031

Table B-3.2: Quantitative Benefits of Natural Gas Related Transportation Projects

Agreement	Project	Project Title	Sector	Application	Technical Potential (million gallons of gasoline & diesel/year)	Market Penetration Estimate/Assumption	Estimated Annual Benefits		Estimated Annual Fuel Cost Savings	GHG Reductions (metric tons/year)
							Number	unit effect		
500-11-004	1	Production of Substituted Natural Gas from the Wet Organic Waste by Utilizing PDU-Scale Steam Hydrogasification Process	Alternative Fuel Production		N/A	Contractor Estimate:	308,790	gasoline-gallon equivalent/yr fossil-derived natural gas displaced by renewable natural gas	unkown	2,072
500-10-053	1	Natural Gas Engine and Vehicle Integration Research	Class 7 & 8 Heavy-Duty Vehicles	-refuse haulers -delivery vehicles -regional haul tractors -furniture trucks -drayage trucks -school & transit buses	975	10%	97.5	million gallons/yr diesel and gasoline displaced by LNG	$48,880,357	966,878
PIR-08-045	1	Lower Cost High Performance and High Efficiency Pilot-Ignited Directly Injected HD Natural Gas Engine	Class 8 Heavy-Duty Vehicles	-large tractor trailers -transit buses -refuse haulers -cement truck -dump truck -sleeper truck	779	33%	257	million gallons/yr diesel and gasoline displaced by LNG	$128,843,607	604,479